ELECTRICAL ENGINEERING

MAY 1960
Vol. 79, No. 5

Contents

Recent Progress in Thermoelectricity *S. J. Angello* 353
Development of good thermoelectric materials and new systems requirements have caused greatly increased activity in the field of thermoelectricity

Measurement of the Parameters in the Thermoelectric Figure of Merit *E. H. Lougher* 358
Methods for measuring thermoelectric parameters, including Seebeck coefficient, thermal conductivity, and electrical resistivity, are described

A Thermoelectric Refrigerating System for Submarines *R. G. Sickert* 364
A discussion of an investigation to determine the feasibility of thermoelectric refrigerating systems for submarines

Measurement of Materials for Thermoelectric Generators *C. S. Duncan, G. W. Wilson* 372
Various aspects of thermoelectric generator material measurements indicating what they can reveal and which ones are needed for a specific purpose

Thermoelectric Refrigeration *W. L. Wright* 380
Practical thermoelectric cooling has become a reality with the development of thermoelectric semiconductor materials

Formation of Proposed Institute Groups *W. A. Lewis* 386
A brief description of the plan for the formation of Institute Groups to serve AIEE members with common interests more closely

Why We Are What We Are *G. C. Baxter Rowe* 388
An explanation of the reasoning behind and necessity for the "horizontal" policy of *Electrical Engineering*

Industrial Computers for Tank Farm Inventory Control and Data Handling *E. B. Turner, R. J. Noorda* 390
Application of an industrial computer system to the information problems of tank farm operation in a relatively large geographical area

Economic Trends Make Railroad Electrification Inevitable *L. B. Curtis* 394
An appraisal of economic and other factors that will lead, it is predicted, to an early revival of railroad electrification in North America

Telemetering Applications and Operation on a Large Power System *D. E. Johannson* 400
The various types of continuous telemetering equipment in use on the Bonneville Power Administration's transmission system are described

An Electrical Essay—The Gravy Train *A. D. Moore* 406

CONTENTS CONTINUED

THE COVER: Two members of the RCA Laboratories technical staff prepare a test of thermal diffusion in a semiconductor crystal as part of the program in thermoelectric power generation at the David Sarnoff Research Center, Princeton, N. J. The crystal, mounted on the structure rising from bottom of picture, will be heated within the cylindrical chamber lowered from above, for measurement of heat distribution through the material. Several articles on various aspects of thermoelectricity appear in this issue. See p. 353.

Published monthly by American Institute of Electrical Engineers

ELECTRICAL ENGINEERING. © Copyright 1960 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and annually by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York 18, N.Y., by the first of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

NIAGARA

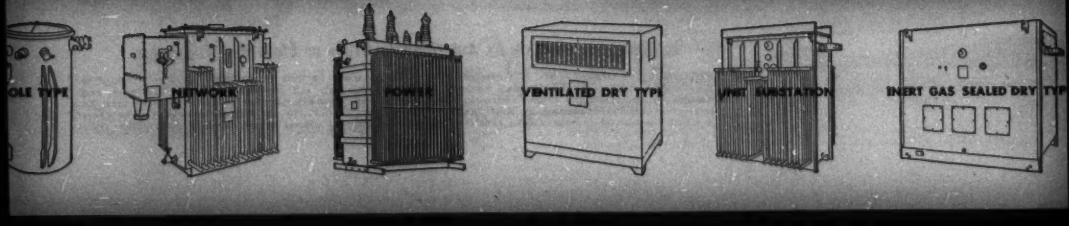
TRANSFORMERS

"You can count on Niagara. Really cooperative. They've never let us down."

Sensitive to the needs of its customers, Niagara has proved its flexibility time and time again in scheduling urgent deliveries. Doing the "impossible" is not uncommon in this organization. Close, personal, *friendly* attention is uppermost. Even shipments are planned to minimize unloading costs.

Built in accordance with established standards or to specified requirements, Niagara Transformers cover practically every service through 10,000 kva, 69,000 volts. Write for Bulletin 139. Niagara Transformer Corp., P.O. Box 23, Buffalo 25, N. Y. Representatives in principal cities.

"There they are . . . we'll have power as scheduled."



Contents Continued

Technical Paper Digests

High-Temperature Effects on Magnetic Core Materials	*Michael Pasnak, Richard Lundsten*	379
Asynchronous Multiplexing	*J. E. Taylor*	385
Stability Criteria for Instrument Servomechanisms	*M. P. Pastel, G. J. Thaler*	399
5005 Aluminum Alloy Cables for Overhead Lines	*H. W. Adams*	405
Convergence of Iterative Load-Flow Studies	*J. E. Van Ness*	407

Departments

Institute Activities

Pacific General Meeting Will Feature Space-Age Electricity	408
AIEE Summer General Meeting Scheduled for June 19-24	409
Lamme Medal Awarded	409
International Conference on Solid-State Circuits	410
Solid-State Electronics Is Topic of Workshop Program	410
AIEE Future Meetings	411
Technical Program for Cement Industry Conference	412
Electronic Components Conference Slated for May	412
Two Sessions Are Planned on Data Transmission Subjects	413
Conference on Domestic Appliances	413
Members To Present Technical Papers at CIGRE	414
AIEE Fellows Elected	420
AIEE Personalities	426
Obituaries	428
Engineering Societies Personnel Service, Inc.	50A

Of Current Interest

Surveillance Radar Subsystem for BMEWS, Site 1	430
Automatic System Lands Two Planes a Minute	432
Future Meetings of Other Societies	433
Microsecond Memory Drives Metallic Contacts	434
Radar Antenna Test Pattern Fixture	435
Reconofax Makes Possible Detailed Aerial Night Photos	436
Unique System Cools Generator Stator Coils	437
Commercial Thermoelectric Generator	438
28-Channel Airborne Miniature Recorder	439
New Books	440
Technical Literature	442
New Products	8A
Industrial Notes	28A
Trade Literature	40A

Statements and opinions given in articles appearing in *ELECTRICAL ENGINEERING* are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters. Published monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

Headquarters, 10th floor • Editorial Offices, 6th floor

33 West 39th Street, New York 18, N. Y.

J. H. FOOTE, President — N. S. HIBSHMAN, Secretary

PUBLICATIONS DEPT., W. F. Denkhaus, *Chairman*; N. H. Muller, *Vice-Chairman*; C. S. Rich, *Secretary*; E. W. Boehne, D. T. Braymer, T. H. Cline, Burke Frick, L. R. Gaty, Lenine Gonsalves, E. I. Green, E. T. B. Gross, W. R. Harris, C. T. Hatcher, D. L. Hemmenway, W. S. Hill, A. W. Kessler, C. W. Leihy, M. S. Merritt, F W. Norris, F. C. Roberts, J. D. Tebo, J. I. Tesar, B. J. Wilson, P. C. Wallace.

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers, publication office Hildreth Press, Bristol, Conn. Editorial and advertising offices, 33 West 39th Street, New York 18, N. Y. Member subscription $6 per year nondeductible from dues; single copy 75 cents. Nonmember subscription $12 per year plus extra postage to all countries to which second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Bristol, Conn., under the Act of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. May 1960. Vol. 79, No. 5. Number of copies this issue, 68,500.

Charles S. Rich
Editor and Manager of Publications

G. C. Baxter Rowe
Associate Editor

Editorial Assistants

G. Charitz

A. M. Fallert

G. Jaari

E. Jacobs

S. Walters

R. E. Whitlock

Advertising

J. S. Lopes
Middle Atlantic Manager
33 W. 39 St., New York 18, N.Y.
Tel: PEnnsylvania 6-9220

J. S. Holzer
Eastern Manager
33 W. 39 St., New York 18, N.Y.
Tel: PEnnsylvania 6-9220

E. R. Bollinger
Central Manager
3758 Cleveland-Massillon Rd.
West Richfield, Ohio
Tel: OLiver 9-4800

A. E. Del Gado
Mid-West Manager
1604 Chicago Ave.
Evanston, Ill.
Tel: GReenleaf 5-1132

T. P. Galavan

A. O. Dillenbeck, Jr.
Western Adv. Office
266 South Alexandria Ave.
Los Angeles 4, Calif.
Tel: DUnkirk 5-3991

333 Kearny St., Rm. 310
San Francisco 8, Calif.
Tel: EXbrook 2-4073

J. C. Brettman
Southern Adv. Office
1915 E. Sunrise Blvd.
Fort Lauderdale, Fla.
Tel: JA 2-6930

Waldo Schraubstader
Market Research Director

Frances Newman
Advertising Production Manager

ABC
Member
Audit Bureau of Circulations

Shown here is a section of final testing area. Voltage tests are being applied to *full reel lengths* of cable before shipment.

ANOTHER BIG REASON WHY YOU SHOULD CONSIDER ANACONDA BUTYL (AB) CABLE

SPECIALIZED QUALITY CONTROL AND INSPECTION

From the start: Raw-material suppliers are required to submit certified test reports. Then, tests and sampling at our plant offer extra protection even before production begins. **To finish:** Here's the final inspection line where the finishing touches are applied and where every inch of cable is carefully inspected. Perhaps you already know that Anaconda test procedures are much above industry standards. But do you know that test voltages on Anaconda Butyl (AB) Cable are 125% of industry standards—that minimum corona level is 150% of rated voltage to ground?

Quality control at Anaconda is *more* than mere testing and inspection. It is built into every manufacturing step. That's why you can be sure your Anaconda cable will be of high quality—why you can be sure Anaconda Butyl (AB) Cable is the finest rubber-insulated cable you can buy.

Everything you need to know about Anaconda Butyl (AB) high-voltage cable is neatly summed up in a new booklet, DM-5903, "Anaconda High-Voltage Durasheath* Cable." For your copy, write to: Anaconda Wire & Cable Co., 25 Broadway, New York 4, N. Y. *Reg. U.S. Pat. Off.

ASK THE MAN FROM

ANACONDA®

ABOUT BUTYL (AB) HIGH-VOLTAGE CABLE

SUSPENSION INSULATORS with CIS*

*Corrosion Interception Sleeve

Above — Section of Futura Porcelain

Vol. 79
1960

New Production Tools

In O-B's new mile-and-a-quarter long mechanized production line are many new tools which help to achieve a higher degree of accuracy . . . uniformity . . . control . . . than was possible before.

This modern equipment assures that the inherent superiority of the Futura design will be faithfully reproduced in every insulator that leaves the production line.

Shown below is a close-up view of the hot-press forming operation which molds the top surface of Futura's new porcelain shape.

A New Insulator!

New design tools, new test tools, new production tools have thus created Futura - - the industry's first new suspension insulator in decades.

Just as important as Futura's extra margin of mechanical and electrical strength, however, is the built-in protection it provides against corrosion damage - - damage which might otherwise destroy this greater strength in the years ahead.

Futura's unique Corrosion Intercepting Sleeve (C.I.S.) has been proved in 15 years of service (to date) in contaminated atmospheres which caused other insulators to fail in as little as four years.

No other suspension insulator protects itself, protects the user, like Futura - - best buy on today's market - - for today *and* tomorrow!

OHIO BRASS COMPANY, MANSFIELD, OHIO
Canadian Ohio Brass Co., Ltd., Niagara Falls, Ont.

Ohio Brass HOLAN

PORCELAIN INSULATORS • LINE HARDWARE • CAPACITORS • LIGHTNING ARRESTERS
BUSHINGS • HOLAN TRUCK-MOUNTED POWER DEVICES AND BODIES • BRONZE VALVES

10025-H23

New and Improved Products . . .

Timer-Counter Megacycle . . .

Utilizing a count-down time base requiring no adjustment and an oven-regulated crystal reference, absolute accuracy is better than ±1 part per million ±1 count. The *MFM-831* all-transistor electronic counter has a Timer range is 3μsec to 1 million frequency range of 10 cps to 1 mc. seconds. Data output is 6 decimal digits of 8-4-2-1 parallel binary-decimal code. Typical applications include audio and power frequency measurements, r-f measurements, telemetry signal and oscillator calibration, stability testing, flow and ratio or phase measurements, and automatic check-out. *Epsco Inc., 275 Massachusetts Ave., Cambridge, Mass.*

Continuously Adjustable Power Supply . . .

Designed for laboratory work where a source of direct current is frequently needed for circuit or transistor testing, this portable power supply will provide filtered d-c output ranging from 0 to 45 volts with a capacity of 0 to 2.5 amperes from a 95- to 130-volt a-c source. The unit is continuously adjustable and stabilized ±1% to any output setting regardless of input fluctuations. *Acme Electric Corp., Cuba, N.Y.*

Circuit Breaker . . .

Development of this product represents another step in a continuing program to reduce the size of molded case circuit breakers without reduction in quality or performance. Width of the new *FJ* breaker is 4½ inches or exactly half that of the J-frame, and its length is 10 inches compared to 11 for the older model. The new breakers are available in 2- and 3-pole construction in current ratings of 70 to 225 amperes and voltages of 600 volts a-c and 250 volts d-c. *I-T-E Circuit Breaker Co., 1900 Hamilton St., Philadelphia, Pa.*

Digital Computer . . .

The introduction of the *2003* represents the latest development in the field of transistorized digital computers. With a capacity for performing 10,000 operations per second, the machine features two 64-word magnetic core buffer systems, the ability to transfer a 64-word block of input, output, or internal information by means of a single instruction, and a 64 plug-in instruction-card system. Inherently a 36-bit (plus sign) parallel stored programmed machine, it has a 4096-word core memory. *General Mills, 9200 Wayzata Blvd., Minneapolis 26, Minn.*

Mammoth Shovel . . .

When completed, this shovel for stripping earth over coal seams will be the largest mobile land machine ever built. With a total working weight of 14 million pounds, the dipper will

be able to scoop in one bite 115 cubic yards of material weighing 173 tons and deposit it 464 feet away. The shovel boom will tower 210 feet in the air while the operator's cab, reached by a passenger elevator, will be five stories above ground. Fifty-two electric motors ranging from ¼ to 3,000 hp and producing 12,000 hp will operate and propel this giant earth mover. *Bucyrus-Erie Co., South Milwaukee, Wis.*

High-Speed Microfilmer . . .

This high-speed machine for microfilming engineering drawings, continuously feeds drawings from a pile, registers them, conveys them under the camera, adjusts the illumination to the proper level, photographs the drawings, and finally discharges them to a delivery pile. Sheets up to 22 by 34 inches are handled by the machine, as are roll drawings up to 42 inches wide. The machine can microfilm up to 1,200 drawings per hour. *The de Florez Co., Inc., 200 Sylvan Ave., Englewood Cliffs, N.J.*

Distribution Oil Switch . . .

A 200-ampere 15-kv oil switch for pole-mounted capacitors, sports field, or street lighting, and used as a load-break isolating switch on rural and suburban distribution systems is solenoid-operated and requires only 2 cycles to open and 6 to reclose. This fast response insures simultaneous operation of all three switches on a 3-phase capacitor bank. The apparatus has a 95-kv basic impulse insulation level, a momentary current rating of 9,000 amperes rms, asymmetrical and a 1-second rating of 6,000 amperes rms, symmetrical. Control voltage is 120 or 240 volts. *Westinghouse Electric Corp., P.O. Box 2099, Pittsburgh 30, Pa.*

Data Storage Disk . . .

Servo-pneumatic read/write heads that are capable of following surface irregularities in a magnetic storage disk are the interesting features of this computer storage unit. The head is pushed toward the storage surface by air pressure. Air escaping through an orifice in the face of the head positions it 300 microinches from the storage surface. Parallel leaf springs provide support

for vertical motion while, during the start-up and shutdown cycle, the spring-loaded head automatically pulls away from the surface to prevent wear and damage. *Aeronutronic Division of Ford Motor Co., Ford Rd., Newport Beach, Calif.*

(*Continued on page 12A*)

Vol. 79
1960

Easy to service You can make inspections easily—cables are fully accessible on open cable-supporting ladders,* or suspended on cable rings. In case of accidental damage, you merely cut out a short section and splice. No need to pull out the cable as you do with conduit.

Easy to add new circuits In the event of changes in plant layout, the simplicity of these systems makes it easy to add new circuits to existing runs. Systems can also be easily and quickly dismantled and reinstalled elsewhere—with a minimum of scrap.

Cable-supporting ladders (either galvanized or aluminum) are manufactured by T. J. Cope Division, Rome Cable Corporation, Collegeville, Pennsylvania.

Insulation The butyl compound insulation (Rozone A) used on Rome's interlocked armored cable is heat-, moisture- and ozone-resistant. Cable can be installed out of doors or in other damp locations safely. Metallic armor provides exceptional mechanical protection.

ROME CABLE
DIVISION OF **ALCOA**
Department 3-50, Rome, New York

☐ Please send me more information on the above.

Name .....
Title .....
Company .....
Street .....
City ..... Zone ..... State .....

ALCOA
ROME CABLE
DIVISION

Safe. Easy to operate.
Rate of voltage application conforms to ASTM standards. Portable models. Floor mounted models.

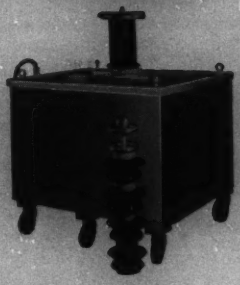
HIGH VOLTAGE

A-C AND A-C/D-C TESTERS

These Sorensen a-c and a-c/d-c testers completely cover the voltage range from 0-150,000 vac and 0-300,000 vdc with current capacities as high as 4000 milliamperes a-c (plus 5 milliamperes d-c for the a-c/d-c units).

All components are conservatively rated to insure maximum life and top performance. Maximum rated current can be drawn continuously over the entire output range and overloads may be supplied for a short time to "burn" faults. Easily reversible d-c polarity of a-c/d-c testers.

New Catalog. Just off the press, Sorensen's new 32-page catalog gives technical data on the complete line of Sorensen a-c and a-c/d-c testers as well as on Sorensen h-v d-c supplies, h-v electrostatic generators, low-voltage d-c power supplies, a-c line-voltage regulators, and frequency changers. Extensive power supply application data is also given. Write for your copy today. Sorensen & Company, Richards Ave., South Norwalk, Conn.



Sorensen

A SUBSIDIARY OF RAYTHEON COMPANY

CONTROLLED POWER PRODUCTS

...the widest line lets you make the wisest choice

New & Improved Products

(Continued from page 8A)

Aluminum Pole . . .

An Alrectic lattice pole, 85 feet long and 2 feet square, has a demonstrated ability to withstand hurricane-force winds up to 140 mph. Four severe windloading tests illustrated the high strength of the lattice pole while supporting three 1.28-inch diameter ACSR conductors and a ⅜-inch high-strength static wire. Designed for use on a 69-kv transmission line, the pole, complete with three 7-foot crossarms, weighs 1,400 pounds or approximately 20% the weight of an equivalent steel pole. *Line Material Industries, Milwaukee 1, Wis.*

Disconnect Terminal . . .

This quick-disconnect terminal assembly is designed to facilitate brush replacement on electric utility equipment or on any motor or generator where the brushes are difficult to reach. The assembly consists of a stationary clip easily bolted to the machine into which one or two terminals can be snapped. *National Carbon Co., 100 E. 42nd St., New York 17, N.Y.*

Ultrasonic Flowmeter . . .

Conventional flowmeters use a mechanical device inside the pipe to measure the flow of liquids. This portable instrument does the job by inducing an ultrasonic beam to pass through the wall of the pipe and echo back to its original source. Since the flow of liquid causes a slight shift in

the beam that is proportional to the speed of flow, this difference is detected as a small voltage differential and read directly on a meter. The circuits are designed to modify this voltage according to the density of the liquid to give volumetric mass flow. *Hersey-Sparling Meter Co., 250 Elm St., Dedham, Mass.*

(Continued on page 14A)

For emergency stopping... **ASCO BREAK-GLASS SWITCH**

In a fire, the quick stopping of equipment such as oil burners and ventilators, can reduce the danger of the fire spreading or explosion. ASCO Break-Glass Switches provide a fast means of stopping equipment from any point throughout your plant.

When glass in switch is broken, switch contacts open and equipment stops. Contacts remain open until glass is replaced.

Designed for use with oil burners, ventilators, air conditioners, refrigeration and a variety of other equipment, ASCO switches feature heavy-duty contacts and solid brass construction for maximum reliability.

They are available single pole, single and double throw, for 2 or 3 wire control devices. Interrupting capacity: 5 amps. at 250V. A-C; 10 amps. at 125V. A-C. Switches come equipped with hammer and have emergency instructions clearly displayed on cover.

For complete information write for Bulletin 124.

Important news for contractors and consulting engineers!
Effective June 1, 1959 New York City Department of Buildings requires each ventilating installation be equipped "with a manual emergency stop located at a conveniently accessible point for quick shutting down of all fans in case of fire."

ASCO Electromagnetic Control
Automatic Switch Co. 50-K HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600
AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO

*7 — *that's the number of Nelson unit substations* originally installed in a single Illinois industrial plant. Just two years later, they added two more Nelson substations in an expansion program.**

What better evidence of complete satisfaction could be desired? Many other industrial plants have found that by standardizing on Nelson equipment they get the ultimate in dependability and easy installation.

This record of proven performance again confirms the fact that Nelson is

BIG ENOUGH TO PERFORM
SMALL ENOUGH TO CARE

Be sure to let your Nelson representative figure your next job. You will find him listed in the Yellow Pages of major city telephone directories.

Write for your copy of the Nelson Pictorial Index.

** *Ask your Nelson man for the facts on this installation.*

NELSON *Electric* MANUFACTURING CO.
TULSA, OKLAHOMA
P. O. BOX 5385 RIVERSIDE 2-5531

New & Improved Products

(Continued from page 12A)

Built-In Protection . . .

A new kind of motor overload protection device that is simple, positive, and fast-acting, is now a feature with the Tri-Clad '55 (registered trade mark) 3-phase induction motor line. Protection is provided by two or more miniature heat-sensing switches buried in the stator windings. When connected in series with a conventional motor control, the switches shut the motor off whenever the internal winding temperature exceeds a predetermined amount regardless of rate of temperature rise. *General Electric Co., Schenectady, N.Y.*

Combination Relay-Timer . . .

A device, which combines the functions of a machine tool relay with a time-delay relay, reduces panel mounting space and installation time ordinarily required if separate devices were used. The timer head provides either time delay after energization or time delay after de-energization and is convertible in the field from one to the other. Timing range is from 0.2 second to 1 minute, ±15%; relay contacts are rated at 10 amperes. *Square D Co., 4041 N. Richards St., Milwaukee 12, Wisc.*

Portable X-Ray . . .

The *PG 300* is a portable industrial X-ray unit that provides high penetrating power and excellent radiographic definition. Completely self-contained, the new unit is shockproof, rayproof, and weatherproof for outdoor operation. Safety devices effectively prevent overloading the tube. The tubehead weighs only 231 pounds

and, therefore, may be hoisted to remote areas for radiography of more than 3 inches of steel. Power requirement is 220 volts, 50/60 cycles, 9 amperes. *Philips Electronic Instruments, 750 S. Fulton Ave., Mount Vernon, N.Y.*

(Continued on page 18A)

FREE YOUR ENGINEERING STAFF FOR MORE CREATIVE WORK . . .

IBM 1620 LOW-COST, DESK-SIZE COMPUTER

RELIEVES YOUR STAFF OF TIME CONSUMING WORK

...SOLVES WIDE RANGE OF SPECIALIZED PROBLEMS

Problems that used to tie up your engineering staff for days can now be solved . . . with electronic accuracy . . . in minutes! The IBM 1620 is a low-cost, desk-size engineering computer that solves a tremendous range of routine and specialized engineering problems quickly and easily. The 1620 offers you an economical way to increase staff productivity, helps pave the way for profitable growth.

The 1620 is easy to learn, easy to operate, easy to communicate with. It adapts readily to specialized and general problems such as design development, blending problems involving matrix arithmetic, research calculations with differential equations. It facilitates the development of mathematical models for plant and shop operation, and evaluation studies employing statistical techniques such as regression analysis.

IBM also makes available a comprehensive library of mathematical routines and programs as well as reliable customer engineering. These services supporting the 1620 are an important part of IBM Balanced Data Processing. They make it easy for you to make full use of the 1620 in your operations without delay. Like all IBM data processing equipment, the 1620 may be purchased or leased.

BALANCED DATA PROCESSING

IBM®

Dept. 805
International Business Machines Corporation
112 East Post Road, White Plains, N. Y.

Please send me further information and complete specifications for the IBM 1620 Engineering Computer. I am particularly interested in:

_____
(engineering application)

NAME _____

POSITION _____

COMPANY _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____

minute
or

MASSIVE

KIRK & BLUM

Electrical Enclosures

Any size . . . any shape . . . any number . . . for whatever requirement . . . KIRK & BLUM fabricating experience and facilities are at your service. Built to exacting specifications . . . we custom fabricate sheet steel, light plate, stainless, aluminum, monel and other alloys to ½" in thickness.

Write for your copy of the latest KIRK & BLUM Electrical Enclosures Booklet . . . for prompt quotation on any job send prints to The KIRK & BLUM MFG. CO., 3204, Forrer Street, Cincinnati 9, Ohio.

Control Desks • Instrument Panels
Electrical Enclosures • Cubicles
Control Panels • Transformer Tanks
Outdoor Electrical Enclosures
Switch Gear Housings • Test Stands

KIRK & BLUM
METAL FABRICATION

New & Improved Products

(Continued from page 14A)

Program Transmitter . . .

A pneumatic program transmitter with interchangeable cams offers a choice of 1, 8, 12, 24-hour, and 7-day cam drives. Designated model *7002*, the device can handle one or two transmission systems, transmit a 3- to 15-psi pneumatic signal, and can be used

with single or double cams. *Weston Instruments Division, Daystrom, Inc., 614 Frelinghuysen Ave., Newark 12, N.J.*

Pocket Cardiac Resuscitator . . .

Designed for external application this resuscitator stimulates ventricular function in cardiac arrests due to drug and anesthesia reactions and those that occur spontaneously as in Stokes-Adams syndrome. Battery operated, the instrument employs a transistorized circuit which completely removes the hazards and nuisance associated with a-c powered instruments. *Medtronic, Inc., 818 19th Ave., N.E., Minneapolis 18, Minn.*

3-Phase Fault Detector . . .

Faults in a 3-phase power system are instantly detected and a visual or sound warning given with this device. Completely transistorized it detects even minute leakages from any phase to ground, thus preventing electrical breakdowns that result in overheating, explosions, motor burnouts, fire, and shock. *General Kinetics Corp., 3151 Kenwood Ave., Burbank, Calif.*

(Continued on page 20A)

SOLVING MATERIAL DESIGN PROBLEMS
HEAT RESISTANCE
A 5000° flame has not penetrated a one-quarter-inch piece of CDF's new Dilecto RD-105 laminate after ten minutes. The same thickness of cold-rolled steel is pierced in less than forty seconds.

Molded from graphite fabric impregnated with a heat (ablation)-resistant phenolic resin, new CDF grades RD-105 and RD-115 are being evaluated in solid propellant rocket motors.

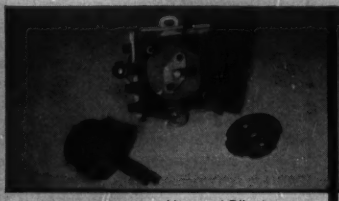
Dilecto laminates are only one family of products from industry's largest selection of non-metallic structural materials and electrical insulations. Vulcanized fibre, silicone rubber, mica, Teflon*, and thermosetting moldings are also supplied by CDF.

CDF can provide both quality and true economy in selecting plastic materials best suited to your needs. Refer to SWEETS PD file or write to us for General Folder 60.

*DuPont trademark

CONTINENTAL-DIAMOND FIBRE

A SUBSIDIARY OF THE Budd COMPANY • NEWARK 86, DEL.



Moisture-resistant and low cost Dilecto cams for automatic washer and dryer controls.

Dimensionally stable, light weight, oil-resistant Dilecto ball bearing retainer rings.

Easily fabricated paper-base, punching grade Dilecto precision switch insulators.

THE ABOMINABLE WHITE ELEPHANT

ON YOUR ELECTRIC BILL

IF YOUR ELECTRICAL SYSTEM is burdened with a low power factor, you're paying for electricity you can't use . . . you're giving up electrical capacity you may need.

The motors and other inductive devices in your plant use both kilowatts (working current) and kilovars (magnetizing current) in order to run. The kilowatts you buy. The kilovars you can best supply yourself. *The more you supply, the higher your power factor, and the less you pay the electric company.*

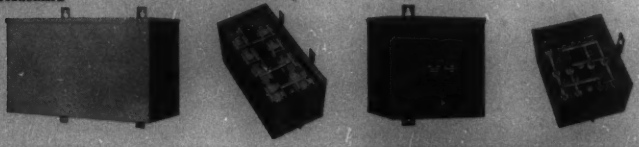
Sprague Unipak* Power Factor Correction Capacitors are the most economical and efficient means of supplying your own kilovars. You put them right where they're needed . . . *at the motors.* Your electric company does not have to send as many kilovars all the way from the power plant, so they charge you less. Your wiring does not have to carry the extra kilovars to the load, so it can handle additional loads.

Actual power bill savings experienced in many plants have more than paid for the Power Factor Capacitors in less than a year's time . . . in some cases, in less than six months. And as an added dividend, these capacitors have also increased the power handling capacity of many plant distribution systems by an average of 20%.

You, too, can reduce costs . . . increase your plant's electrical capacity by installing Sprague Unipak* Power Factor Correction Capacitors. Ask for our handy slide rule calculator which quickly and easily shows the capacitors you need to effect such savings at each load.

Better yet, for *free* assistance in making a complete survey of your electrical installation to see how *much* you can save with Sprague Unipak* Power Factor Capacitors, write Industrial Capacitor Division, Sprague Electric Company, 321 Marshall Street, North Adams, Massachusetts.

*Trademark



WORLD'S LARGEST CAPACITOR MANUFACTURER

SPRAGUE®
the mark of reliability

New & Improved Products

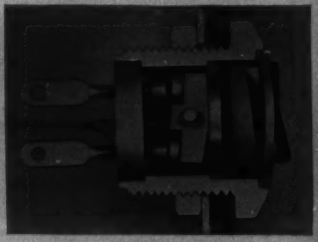
(Continued from page 18A)

Reversible Potting Compound . . .

This compound has the appearance of plaster of Paris when cured, yet it will dissolve readily when the potted unit is placed in a liquid solvent. The dissolving action is so rapid that it is possible to direct a stream of solvent at a specific area without dissolving the entire unit. The thermal conductivity of the material is 0.0008 calorie per degree C per cm per sec and volume resistivity is 10^{12} ohm-centimeters; specific gravity is 1.2 and temperature range is −65 to +250 F. *Video Instruments Co., 3002 Pennsylvania Ave., Santa Monica, Calif.*

Fail-Proof Switch . . .

This microminiature switch uses a new concept to achieve optimum environment and fail-proof characteristics. All elements are hermetically sealed, a magnetic flux being the operating link between the outer



switch button and the make-break electrical contacts within the sealed chamber. The switch contains no springs, a common cause of failure, since the magnet on the outer position attracts and holds the inner snap-action contact rocker from moving. *Space Components, Inc., 1048 Potomac St., N. W., Washington, D. C.*

Frequency Standards . . .

Developed for laboratory and field standard use, the *FS-100* is transistorized and portable, yet maintains a stability of ±1 part in 100 million in any frequency ranging from 10 kc through 20 mc. Life expectancy is 25,000 hours with minor maintenance. Input is 115 volts a-c; output 1 volt peak-to-peak into a 1-kilohm sine or square wave. A self-contained battery source is optional. *Bulova Watch Co., Inc., Electronics Division, 40-01 61st St., Woodside 77, N.Y.*

(Continued on page 26A)

Recent Progress in Thermoelectricity

S. J. ANGELLO
MEMBER AIEE

To stimulate the development of thermoelectricity, a number of articles have been prepared for *Electrical Engineering* by prominent representatives of this important field. Some of the concepts and recent progress are reviewed in this first article.

THE PAST FOUR YEARS have brought forth more activity in thermoelectricity than has any similar period in the more than 100 years since the discovery of the Seebeck and Peltier effects. At least two forces have contributed to the renewed activity: (1) The expanding technology of semiconductors brought about by the inventions of the transistor and p-n junction rectifier has stimulated developments in many solid-state devices, and success with germanium and silicon has encouraged extension of fundamental transport studies to other semiconductors; (2) New systems requirements for electric devices utilize the unique capabilities of static, solid devices, thus placing a forced draft under the development of certain specific devices.

Thermoelectricity has felt both of these forces. Better understanding of electrical and thermal transport in solids has made possible the development of guiding rules for the selection of some potentially good thermoelectric materials. Narrowing the field from among thousands of compounds exhibiting electrical conductivity is of substantial assistance in thermoelectric development. Both the Seebeck generator and Peltier heat pump are electronic devices, that is, there is no transport of matter in their operation. One consequence is that the operation is independent of gravity forces. In particular, zero gravity encountered in earth satellites and space probes is no problem. Since the electronic phenomena involve no mechanical motion or rotation, lubrication problems are not present, and there are no gyroscopic moments to interfere with guidance and stabilizing systems on space vehicles. Simplicity of device configuration and absence of moving parts hold a potential for greater reliability and longer life than may be obtained with mechanical systems. In some missions, complete freedom from noise and vibration is essential. Static devices fill this requirement. Other useful characteristics of thermoelectric devices will be evident as the discussion proceeds.

RECENT HISTORY OF THERMOELECTRIC CONCEPTS

SEVERAL ACCOUNTS[1,2] have reviewed the early history of thermoelectric effects. This review will survey the recent, interesting developments in both power generation and refrigeration.

For pioneering work in thermoelectric power generation in the period preceding 1947, credit should be given to M. Telkes[2] who attained on the order of 5% efficiency from ZnSb–PbS thermocouples. Her attack upon the problem was sound, but semiconductor technology in 1939 was not sufficiently advanced to permit rapid progress. Also, at this time the need for static conversion devices was not as great as it is today.

Another pioneer in both generation and refrigeration was A. F. Ioffe[1,3] who has been prominent also in the development of semiconductor technology in Russia. Prof. Ioffe has chronicled his own trend of thought in thermoelectric developments in his book.[1] Earlier workers[4] had recognized that three parameters determine the efficiency that can be realized in a thermoelectric generator and in a Peltier refrigerator. These are the Seebeck coefficient α, the electrical resistivity ρ, and the thermal conductivity κ. The most commonly used relation among these parameters is the "Ioffe Z"

$$Z = \frac{\alpha^2}{\rho \kappa}$$

A simple derivation of this relation is given in Appendix I. The dilemma of thermoelectricity is made evident by a study of the value of Z as the density of current carriers is varied. We shall remark parenthetically that our ability to vary carrier density is part of the recent technological advance in semiconductors. From the physics of semiconductors we learn that α decreases, as n increases, and $1/\rho = \sigma$ increases as n increases, where n is current carriers per unit volume. Low carrier densities ($\sim 10^{14}/cm^3$), such as those found in insulators, result in α of millivolts per degree C, while the high values of metals ($\sim 10^{22}/cm^3$) give microvolts per degree C. At the same time, resistivities range from hundreds of ohm-cm to 10^{-6} ohm-cm. For every material there is, then, an optimum value for n which gives a best value for α^2/ρ. The best value of α^2/ρ depends upon the value of α and ρ. We wish, therefore, to have ρ as small as possible at optimum n. To see how to accomplish this, another concept is involved. That is,

$$\sigma = n q \bar{v}$$

Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., Jan. 31–Feb. 5, 1960. Recommended for publication by the AIEE Solid State Devices Committee.

S. J. Angello is with the Westinghouse Electric Corporation, Pittsburgh, Pa.

where

q = electron charge
v = mobility or velocity of the charge per unit electric field strength

Mobility is a complicated concept, but for our purpose it is related to the amount of scattering, or the number of collisions a conducting charge makes while drifting down a conductor. We wish to have large values of v. These can come from proper selection of basic compounds and proper treatment thereof.

So far, κ has been treated as independent of n. Actually, κ measures the total heat conducted by the atoms of the crystal and heat conducted by the current carriers. That is,

$$\kappa = \kappa_{crystal} + \kappa_{carriers}$$

The crystal component is usually quite large compared with the carrier contribution except in materials of very high Z. For some purposes, then, the heat conductivity of the crystal is treated as a separate problem. The earlier attempts to select materials of low κ value centered around heavy elements with weak binding forces, such as lead, bismuth, tellurium, and selenium compounds. Crystals of this nature transmit heat poorly. An additional concept was contributed by Ioffe who reasoned that two binary compounds, such as Bi_2Se_3, could be alloyed to form a mixed crystal without substantial mobility change, while at the same time κ would be lowered by the crystal disorder presented to heat traveling through. This idea, whether rigorously correct or not, has resulted in ternary compounds of bismuth, tellurium, selenium, antimony, and other elements which have the highest Z values of any presently known thermoelectric materials.

Semiconductors of the silicon and germanium type have the general disadvantage of a temperature limitation due to "intrinsic" conduction. At temperatures above the onset of intrinsic conduction, the resistivity is no longer controllable by impurity additions, but has a low value entirely dependent upon temperature. The low value of ρ is favorable but, in general, the value of α tends to zero. The reason for this is that in intrinsic conduction the Seebeck effect of electrons (n-type conduction) and holes (p-type conduction) tend to cancel one another in most cases.

This property eliminates many semiconductors from operation at temperatures above about 600 C. For example, p-type Bi_2Te_3 is good to about 150 C which is 400 degrees C below the melting point. It is clear that for high-temperature operation of thermoelectric materials, a nonintrinsic semiconductor type is needed. The concept for the type of material needed to operate in the 1,000 C range was provided in 1947 by C. Zener.[5] Many insulating crystals do not show intrinsic conductivity at very high temperatures, but the resistivity is too high to yield a high Z as a thermoelectric material. Extending results of conductivity studies[6] of ferromagnetic compounds, Zener reasoned that the conductivity of certain insulators may be varied by "mixing the valence," and that an optimum useful value of Z should be obtained in the transition metal compounds. Thus, for example, the insulator nickel oxide, $Ni^{++}O^{--}$ can be modified by addition of Li^{+} to form the mixed valence compound $Li_z^{+}\ Ni_x^{+}\ Ni_{1-z}^{++}\ O^{--}$, in which Ni has a mixture of valence +1 and +2. Conductivity is effected by charge exchange among the nickel sites. The magnitude of resistivity depends upon the fraction x of added lithium. Ten per cent of lithium can change the resistivity from hundreds of ohm-cm to the order to 10^{-2} ohm-cm.

The mixed valence compounds of the Fe, Co, Ni series turned out to have too high a thermal conductivity to give high Z values, but the rare-earth compounds have many examples of refractory thermoelectric materials with good potential for high efficiency.

Development of thermoelectric materials is having a favorable effect upon the understanding of mixed valence materials. New properties are being uncovered which will result in more sophisticated criteria for thermoelectric material selection and, consequently, materials of higher Z value.

Experience has shown that once substances with good potential thermoelectric properties are exhibited, the exploitation of these materials is a long and arduous task. Two outstanding examples will illustrate this experience. At least 10 years of research and development, including 5 years of life testing, were invested in lead telluride for power generation by Drs. Sebastian Karrer and R. W. Fritts.[7] Seebeck coefficients and resistivity as a function of composition and temperature have been mapped for both n- and p-type PbTe. Much life data has been accumulated which places upper limits of temperature for various types of environment. In spite of all this work there are still details concerning bonding of hot contacts and structural strength of PbTe to be finally resolved. In the case of Peltier cooling materials, the General Electric Company[8] in Wembly, England, has carried out a great amount of development work for about 5 years to attain a cooling of 66 degrees C from 290 degrees Kelvin.

As more general techniques for contacting semiconductors and encapsulating them against harmful environments are developed, it may be hoped that the rate of progress in thermoelectric materials development will increase.

SUMMARY OF THE THEORETICAL UNDERSTANDING OF THERMOELECTRICITY

From the standpoint of thermodynamics, the phenomena of thermoelectricity in solids have been understood for many years. The work of Kelvin and Bridgeman,[9] and more recently the irreversible thermodynamics of Onsager,[10] has brought the subject to a high state of development.

More recent theoretical developments have been concerned with the physics of semiconductors aimed at providing materials with high Z values. This work has been alluded to in the previous section. A third avenue of theoretical development is the careful description of

efficiency and coefficient of performance of devices with the purpose of realizing the full potential of the Z value of thermoelectric material.

Efficiency of conversion of heat to electric power is very important, because the practical use of the Seebeck effect depends heavily upon the value of this number. First, efficiency η may be defined. This is the ratio of electric power dissipated in a load to the rate of heat flux entering the hot junctions of a thermocouple system, that is,

$$\eta = \frac{P_L}{Q}$$

This is not the usual figure for the efficiency of a heat engine. Efficiency is more commonly the electric energy divided by the Btu content of the fuel. The thermoelectric definition isolates the thermoelectric device from the efficiencies of combustion, heat transfer in a duct, and the like.

It is common to refer a thermoelectric device efficiency to the Carnot cycle. For example $\eta = \eta_{tc}\,\eta_{\text{Carnot}}$ where the thermocouple efficiency η_{tc} is the fraction of the best theoretical efficiency which can be obtained by a heat engine working between a source at T_h and a sink at T_c degrees Kelvin.

For values of α, ρ, and κ which are independent of temperature, Ioffe[2] has given η as

$$\eta = \frac{T_h - T_c}{T_h}\left[\frac{\sqrt{1 + Z\,T_{av}} - 1}{\sqrt{1 + Z\,T_{av}} + \frac{T_c}{T_h}}\right]$$

for the efficiency of one couple, Fig. 1, with parameters α_1, ρ_1, κ_1, and α_2, ρ_2, and κ_2, for the respective legs. The first factor is η_{Carnot} and the second factor reduces to

$$\eta_{tc}(T) = \frac{\sqrt{1 + ZT} - 1}{\sqrt{1 + ZT} + 1}$$

when T_h and T_c are nearly the same temperature, and

$$\frac{T_h + T_c}{2} = T_{av} = T$$

The Z value for a couple is

$$Z = \frac{(\alpha_1 - \alpha_2)^2}{(\sqrt{\rho_1\kappa_1} + \sqrt{\rho_2\kappa_2})^2}$$

If leg 1 is referred to a superconductor in which $\alpha_2 = 0$ and $\rho_2 = 0$, we have the usual

$$Z = \frac{\alpha_1^2}{\rho_1\,\kappa_1}$$

In general, real thermoelectric materials have Z values which are not independent of temperature and the highest values for Z for a given material are in a restricted temperature range. Obvious questions which arise are (1) how does the temperature dependence of Z affect the performance of generators and refrigerators, and (2) how may several thermoelectric materials which are good in different temperature ranges be combined to yield high efficiency.

A general observation may be made concerning the first question. If temperature dependences of α, ρ, and κ are considered, the basic equations become nonlinear

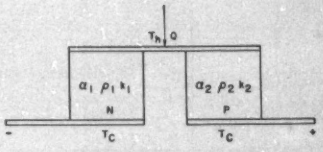


Fig. 1. Thermoelectric couple.

and must be solved numerically or by computer. Such studies have been carried out by B. W. Swanson et al[11] and B. Sherman et al.[12] General results are that temperature dependence of Z can be quite detrimental to Peltier heat pumps under certain conditions. Parameters α, $\bar{\rho}$, and $\bar{\kappa}$ averaged over the temperature range can be used to a good approximation in power generator[13] efficiency calculations. Staging of thermoelectric materials in thermal series is theoretically superior to constructing single thermocouple legs segmented with different materials. This result is the general answer to question 2. Fig. 2 illustrates what is meant by staging couples. Harmon[14] has discussed finite numbers of stages and Zener[15] has described infinite staging. A convenient result of the Zener description is that $\eta_{tc}(T)$ may be plotted for different materials as a function of

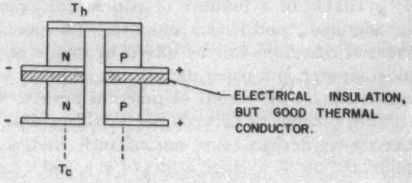


Fig. 2. Two stages of thermoelectric couples in thermal series.

ln T. The area between two temperature lines is the maximum theoretical efficiency η which can be obtained from the materials in this temperature range. Thus,

$$\eta = 1 - \exp\left[-\int_{T_c}^{T_h} \eta_{tc}(T)\,d\,(\ln T)\right]$$

$$\eta = \int_{T_c}^{T_h} \eta_{tc}\,(T)\,d\,(\ln T)$$

Figs. 3 and 4 shows plots of $\eta_{tc}(T)$ for n and p materials, respectively, with a theoretical efficiency of 18% between 1,000 C and 30 C.

The maximum theoretical efficiency is obviously degraded in a device if contact resistance exists within the

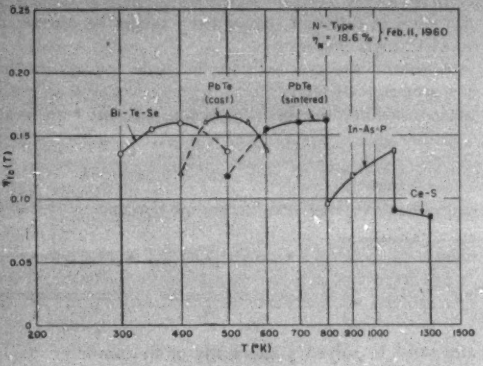


Fig. 3. N-type materials.

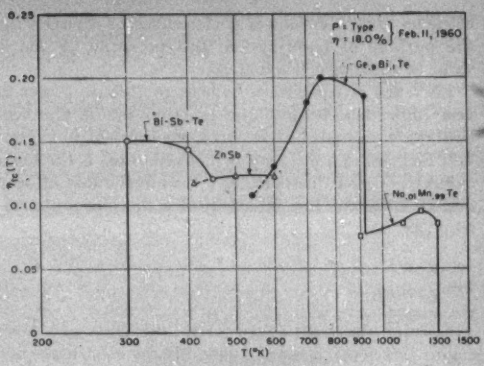


Fig. 4. P-type materials.

circuit and if some source of heat is lost to the thermocouples by extraneous heat conduction paths and chimney losses. For maximum efficiency, a heat source of constant temperature T_h is preferred. Real fuel fired devices have values of T_c varying along the heat exchanger[16] which further degrades the theoretical efficiency.

In the domain of theory, the Seebeck and Peltier effects are intimately related. In practice, however, the techniques of devices diverge widely. The basic reason is the high-temperature problems encountered in power generation not yet faced by heat-pumping devices.

The theory of heat pumping will not be surveyed in detail in this article, because coherent accounts are already available in a number of papers, for example, Ioffe,[1] Sherman,[12] and Heikes and Ure.[13] The nonlinear differential equations can be solved by means of electronic computer, and paper designs can be made which approach closely the results of practical devices. Some interesting differences between Seebeck generator and Peltier cooler devices come out of such studies. For example, the use of average values of α, ρ, and κ can be in serious error in heat pumping devices, because the Peltier heat pumped is in opposition to conducted heat. This leads to differences of comparable heat rates. In the Seebeck case, Peltier and conducted heat have the same direction of flow.

PRESENT STATUS OF MATERIALS DEVELOPMENT

Figs. 3 and 4 summarize the state of the art at the time of this writing. It is to be hoped these data will rapidly become obsolete by virtue of the great effort being expended in many laboratories in the United States. Much of this research and development effort is to be credited to the forward looking policies of the U. S. Navy Bureau of Ships. Various contracts under the cognizance of the Bureau support work on mixed valence compounds, semiconductors, liquid thermoelectric materials, and semimetals. Some of this work is described in the accompanying articles on thermoelectricity appearing in this issue of *Electrical Engineering*.

Semiconductors and semimetals cover the power generation temperature range from 25 C to about 600 C. Above this temperature, the mixed-valence-type materials, such as samarium sulphide, are being developed. An interesting result of the study of mixed-valence materials is that the current carriers behave as if the carrier mass is 100 or more times the mass of a free electron. One consequence of this is that the optimum Z value comes at a higher value of carrier density than in the semiconductor case. The material is, thus, less sensitive to radiation damage effects, and a more indirect consequence is that heat transferral by radiation from the hot surface through the material to the cold surface is negligible, even above 1,500 C.

In the case of Peltier cooling materials, best results are being obtained with complex alloys of Bi_2Te_3 with Se, Sb, and the like. The highest reliable values of Z appear to be in the neighborhood of 3×10^{-3} per degree C.

PELTIER COOLING DEVICES

The first demonstration that enough cooling could be obtained by the Peltier effect to build a refrigerator was given by the work of Nils Lindenblad.[17] Much of the effort since that time has gone into the design and construction of various devices to test the feasibility and develop assembly techniques. We shall mention the Wonderbar of RCA Whirlpool and the hostess cart and baby bottle cooler/warmer of Westinghouse Electric Corporation. Other new devices and applications are described in some of the accompanying articles.

THERMOELECTRIC POWER GENERATORS

The technical development of thermoelectric power generators has been slower by about 2 years behind the Peltier cooling devices. One reason is that the incentive of large-scale consumer product applications is stronger in the case of Peltier cooling. Some significant work has been done, however, especially by the military. For example, the Rome Air Development Command sponsored a bismuth telluride power generator which was

constructed by Horizons, Inc.,[18] in 1957. The Signal Corps has sponsored the development of a small generator to convert the heat of Po-210 isotope to electric energy.[19] Recently, the Martin Company and the Minnesota Mining and Manufacturing Company[20] have constructed a small generator of lead telluride alloys to show the feasibility of a Po-210 radioactive source for a satellite power supply.

Appendix

DERIVATION OF THE FIGURE OF MERIT Z

The following derivation may be of interest to electrical engineers. Consider a thermoelectric material pellet carrying a flow of heat Q. A temperature gradient ΔT appears in the direction of flow and a voltage V_0 appears across the temperature gradient according to the Seebeck effect. The pellet may be considered to be a d-c battery with open circuit voltage V_0 in series with an internal resistance r.

Maximum power is extracted from this battery when the load resistance R_L equals r. Thus,

$$P_L = \frac{V_0^2}{4r}$$

The Seebeck coefficient α is given by

$$V_0 = \alpha \Delta T$$

The internal resistance r can be expressed in terms of resistivity ρ and the geometry as

$$r = \frac{\rho l}{A}$$

The thermoelectric efficiency is

$$\eta = \frac{P_L}{Q}$$

The heat rate is given by the expression

$$Q = \kappa \frac{A}{l} \Delta T$$

Now P_L in terms of thermoelectric parameters is

$$P_L = \frac{\alpha^2 (\Delta T)^2}{4 \frac{\rho l}{A}}$$

Divide by Q to give

$$\frac{P_L}{Q} = \eta = \frac{\alpha^2 (\Delta T)^2}{4 \frac{\rho l}{A} \kappa \frac{A}{l} (\Delta T)}$$

The geometry cancels out and the efficiency becomes

$$\eta = \frac{\alpha^2}{4 \rho \kappa} \Delta T$$

Multiplying and dividing by T_h introduces the Carnot efficiency, and

$$\eta = \frac{T_h}{4} \left(\frac{\alpha^2}{\rho \kappa} \right) \left(\frac{\Delta T}{T_h} \right) = \eta_{te} \eta_c$$

This states that η is the Carnot efficiency $\eta_c = \Delta T / T_h$ reduced by a factor called the thermocouple efficiency η_{te}. The materials parameters in η_{te} are related by

$$Z = \frac{\alpha^2}{\rho \kappa}$$

This derivation has been simplified by ignoring the Peltier and Joule contributions to the heat rate Q. The more complicated derivation which includes these terms still utilizes the form

$$Z = \frac{\alpha^2}{\rho \kappa}$$

REFERENCES

1. Semiconductor Elements and Thermoelectric Cooling (book), A. F. Ioffe. Infosearch, Ltd., London, England, 1957.

2. The Efficiency of Thermoelectric Generators, Maria Telkes. *Journal of Applied Physics*, New York, N. Y., vol. 18, 1947, pp. 116-27.

3. The Revival of Thermoelectricity, A. F. Ioffe. *Scientific American*, New York, N. Y., vol. 99, Nov. 1958, pp. 31-37.

4. E. Altenkirch. *Physikalische Zeitschrift*, Leipzig, Germany, vol. 10, 1909, p. 560, vol. 12, 1911, pp. 920-24. P. O. Gehlhoff, E. Justi, M. Kohler. *Abhandlungen*, Braunschweigischen Wissenschaftlischen Gesellschaft, Brunswick, Germany, vol. 2, 1950, pp. 149-64.

5. The Impact of Thermoelectricity upon Science and Technology, C. Zener. Symposium edited by Paul Egli, McGraw-Hill Book Company, Inc., New York, N. Y. 1960.

6. Interaction Between the D-Shells in the Transition Metals II Ferromagnetic Compounds of Manganese with Perovskite Structure, C. Zener. *Physical Review*, New York, N. Y., vol. 82, 1951, pp. 403-05.

7. Designing Parameters for Optimizing the Efficiency of Thermoelectric Generators Utilizing P-type and N-type Lead Telluride, R. W. Fritts. AIEE *Transactions*, pt. I (*Communications and Electronics*), vol. 78, 1959 (Jan. 1960 section), pp. 817-20.

8. The Performance of Bismuth Telluride Thermojunctions, H. J. Goldsmid et al. *British Journal of Applied Physics*, London, England, vol. 9, 1958, pp. 365-70.

9. Heat and Thermodynamics (book), M. W. Zemanski. McGraw-Hill Company, Inc., 1957, pp. 298-309.

10. Irreversible Thermodynamics of Thermoelectricity, C. A. Domenicali. *Reviews of Modern Physics*, New York, N. Y., vol. 26, 1954, pp. 237-75.

11. Optimization of a Sandwiched Thermoelectric Device, B. W. Swanson, E. V. Somers, R. R. Heikes. Scheduled for publication in *Transactions*, American Society of Mechanical Engineers, New York, N. Y., 1960.

12. Calculation of Efficiency of Thermoelectric Devices, B. Sherman, R. R. Heikes, R. W. Ure. *Journal of Applied Physics*, vol. 31, 1960, pp. 1-16.

13. Interscience (book), R. R. Heikes, R. W. Ure, editors; Chapter 17, "Science and Engineering Thermoelectricity," S. J. Angello. To be published July 1960, Interscience Publishers, Inc., New York, N. Y.

14. Multiple Stage Thermoelectric Generation of Power, T. C. Harmon. *Journal of Applied Physics*, vol. 29, 1958, pp. 1471-73.

15. Thermoelectric Conversion, C. Zener. *Proceedings*, Seminar on Advanced Energy Sources and Conversion Techniques, vol. I, ASTIA no. AD209301, 1958, pp. 95-98.

16. Optimization of a Conventional Fuel Fired Generator, B. W. Swanson, E. V. Somers. *Transactions*, American Society of Mechanical Engineers, series C, vol. 81, no. 3, 1959, pp. 245-49.

17. Thermoelectric Heat Pumping, N. E. Lindenblad. *Electrical Engineering*, vol. 77, Sept. 1958, pp. 802-06.

18. Design Considerations for the Radioisotope Thermoelectric Generator, Lt. F. B. Brauer et al. *Technical Report*, ASTIA Document no. AD-97849, Rome Air Development Center, Rome, N. Y., Jan. 1957.

19. Nuclear Battery—Thermocouple Type, K. C. Jordan et al. MLM-CF-58-4-49, Jan. 1, 1958, MLM-CF-58-1-40, Oct. 1, 1957, Mound Laboratory, Miamisburg, Ohio.

20. An Elementary Design Discussion of Thermoelectric Generation, E. W. Bollmeier, *Electrical Engineering*, vol. 78, Oct. 1959, pp. 995-1002.

21. SNAP III—Practical Power from Radionucleides, M. Barmat, G. M. Anderson, E. W. Bollmeier. *Nucleonics*, New York, N. Y., vol. 17, no. 5, 1959.

THERMOELECTRICITY

Measurement of the Parameters in the Thermoelectric Figure of Merit

E. H. LOUGHER

Some of the more effective methods for measuring such important parameters of thermoelectric materials as Seebeck coefficient, thermal conductivity, and electrical resistivity are described.

THE VALUE of a material for use in pumping heat by the Peltier effect or in generating power by the Seebeck effect may be expressed in terms of a figure of merit which takes into account the magnitudes of the desired thermoelectric effects and the losses incurred through Joule (I^2R) heating and thermal conduction. The most often used figure of merit is defined as

$$Z = \frac{\alpha^2}{\kappa \rho}$$

where

α = Seebeck coefficient (thermoelectric power)
κ = thermal conductivity
ρ = electrical resistivity

Measurement of these properties for metals, which usually can be prepared in the form of long rods or wires with good homogeneity, is reasonably straightforward. On the other hand, most semiconductors—the materials of interest for thermoelectric applications—are not ductile and, hence, are not available in wire form. In addition, homogeneous specimens of the large size required for some methods of measuring thermal conductivity are difficult to prepare. For these reasons, some of the measurement techniques used for other materials cannot be used, and others require modification.

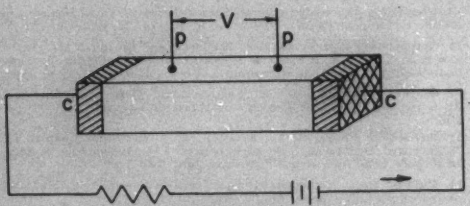


Fig. 1. A 2-probe resistivity apparatus.

In the following sections, some of the better methods for measuring the Seebeck coefficient, thermal conductivity, and electrical resistivity of thermoelectric materials are discussed. The discussion of each technique is necessarily brief; references are given to more detailed descriptions. Throughout, it is assumed that the specimens under measurement are reasonably homogeneous, i.e., that they do not contain large cracks or voids, and that the electrical and thermal properties are uniform throughout the material.

ELECTRICAL RESISTIVITY

SINCE an electrical contact to a semiconductor may have resistance which is appreciable compared with the specimen resistance, a 2-terminal measurement method, such as with an ohmmeter or with a voltmeter and ammeter, is not a satisfactory means of measuring electrical resistivity, unless it is known in the case under study that low-resistance contacts can be made reproducibly. To eliminate the effect of contact resistance, 4-terminal techniques are commonly used.

The 2-probe Method. One 4-terminal technique, the "2-probe" method, is illustrated in Fig. 1. Current is passed through the specimen by means of the contacts c on the ends, and the potential difference between the probes p is measured. The resistivity is given by

$$\rho = \frac{VA}{Id}$$

where

V = voltage measured between the probes
I = current
A = cross-sectional area of the specimen
d = distance between the probes.

The voltage and current are best measured by means of potentiometers, although voltmeters and ammeters may be used.

If direct current is used, a temperature gradient is developed along the specimen as a result of the Peltier effect. The temperature gradient, in turn, gives rise to a Seebeck emf (electromotive force) which adds to the IR drop V between the probes. In a good thermoelectric material, this emf may be comparable with the IR drop,

A special article recommended by the AIEE Solid State Devices Committee.

E. H. Lougher is with the Battelle Memorial Institute, Columbus, Ohio.

The author wishes to thank Drs. A. C. Beer, H. L. Goering, and P. W. Davis for their helpful comments on the manuscript.

so that the value obtained for the resistivity is seriously in error. This error may be reduced by measuring the probe voltage, reversing the current, and quickly measuring the voltage again, before the temperature gradient can change appreciably. In principle, the two measured voltages are, respectively, the sum and difference of the IR drop and the Seebeck emf, so that the average of the two values is the IR drop. In practice, it is difficult to make the second measurement before significant decay of the gradient takes place; however, resistivity values accurate within a few per cent may be obtained by this method. The accuracy may be improved by immersing the specimen in a liquid to reduce the temperature gradient.

A better technique for avoiding the error caused by the Peltier effect is to use alternating current, so that no temperature gradient is established. Potentiometric measurements may be used.[1, 2] A simple and accurate method involves the use of a square-wave current, supplied by a mechanical chopper, in conjunction with a d-c potentiometer, a galvanometer, and a battery or d-c power supply.[3-5] The chopper has two synchronized sets of double-pole double-throw contacts, one set to reverse the specimen current, the other to interchange the connections from the probes to the potentiometer. The timing of the contacts is such that the potentiometer is connected to the probes only during the central portion of a half cycle of the square wave (the portions AB in Fig. 2) to avoid errors resulting from contact chatter and the finite rise time of the voltage. Measurements can be made on thermoelectric materials by the chopper technique with accuracy comparable with that of ordinary d-c potentiometric measurements on materials for which errors arising from the thermoelectric effects are negligible.

Certain precautions must be observed in contacting a specimen for measurement. The equipotential surfaces touching the probes must be parallel planes. This requirement implies that for a homogeneous material, the current-density vector must be parallel to the longitudinal axis of the specimen and its magnitude must be constant throughout the portion of the specimen between the probes. To insure this uniformity the probes should, if possible, be placed far enough from the ends of the specimen to avoid the effects of spreading resistance at the current contacts (at least a diameter, in the case of cylindrical specimens). For specimens which are too short for this method, metal blocks may be soldered to the ends, covering the entire end surfaces, so that the spreading resistance is in the metal rather than in the specimens. For cylindrical specimens, copper blocks the same diameter as the specimen and at least one third this long will give adequate current uniformity for the materials encountered in thermoelectric work.

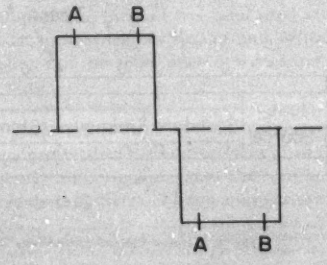
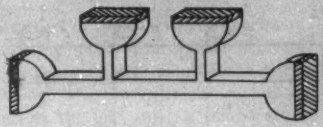


Fig. 2. Square wave for resistivity measurements.

Fig. 3. Bridge-type specimen.



The probes may be spring-loaded pressure contacts or may be attached to the specimen by soldering or other means. Pressure contacts work well if the contact resistance is low enough over the temperature range in which measurements are being made. Soldering has the disadvantage that the area of contact is rather large, so that for small specimens with a short distance between probes there is some uncertainty in the value of the probe spacing. Spot welding is used frequently, but the high temperature involved in making the weld may cause a change in specimen properties in the vicinity of the weld. A method which works well with some materials is to drill a small hole (0.010 to 0.020 inch) in the specimen and insert a tightly fitting wire. One of the best techniques is use of the bridge-type specimen (Fig. 3), which is cut ultrasonically with a die. The wide current contacts minimize errors resulting from spreading resistance. The probes are part of the specimen itself, so that distortion of the electric field at the probe-specimen junctions is small. Also, the geometry of the probe-specimen system is reproducible and can be measured accurately.

The 4-Probe Method. This method is useful for rapid measurements. Four collinear pressure-probes are used, the two end probes being used as current contacts (Fig. 4). If the probes are equally spaced by distance d, and if the diameter of the contact area is much less than d, the resistivity is given by $\rho = 2\pi Vd/I$, provided all sample dimensions are large compared with the probe spacing and the probes are not near an edge of the sample. If these conditions are not met, correction factors may be used to calculate the resistivity.[6] The accuracy of the 4-probe method is not high, particularly if the specimen has a surface region of resistivity different from that of the bulk material. At best, errors of several per cent may be expected. As with the 2-probe technique, alternating current may be used to eliminate the error resulting from thermoelectric effects.

Other Methods. A few other methods which are sometimes used for measuring electrical resistivity will be mentioned briefly. The reader is referred to other accounts for details.[7]

Two-terminal methods are sometimes used for resistivity measurements when it is known that the contact resistance is small. The "spreading-resistance"

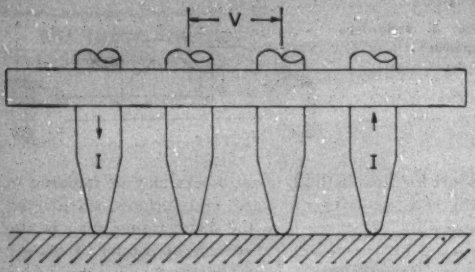


Fig. 4. A 4-probe resistivity apparatus.

method is a 2-terminal technique which is useful for studying the homogeneity of a surface. It is essentially an ohmmeter method using a point probe and a single large-area contact. Accuracy is low, since the area of contact is not known accurately. In addition, as with the 4-probe method, accuracy is affected if the surface region of the specimen has a resistivity different from that of the bulk material.

Bridge techniques also may be used if contact resistance is low. The Kelvin bridge reduces the effect of contact resistance on the measurements.

An inductive method has been used for measurements on low-resistivity materials.[8] A circulating current is induced in the specimen by a small coil held near the surface. The resistivity is determined from the back emf induced in the coil.

THERMAL CONDUCTIVITY

THE THERMAL CURRENT DENSITY, i.e., the rate of heat transfer across unit area, in a homogeneous, isotropic solid in which radiation is negligible is given by

$$\vec{q} = -\kappa \nabla T$$

For 1-dimensional flow along a rod of uniform cross section and with a constant temperature gradient along the rod, this equation becomes

$$\vec{q} = Q/A = -\kappa \frac{\Delta T}{\Delta x}$$

where

Q = rate of heat transfer
A = cross-sectional area of the rod

Thus, the direct measurement of thermal conductivity reduces to measurement of a heat-flow rate, a temperature difference, and the geometry of the system. Although in principle the measurement is simple, in practice extraneous heat transfer causes uncertainty in the value of Q, and for small specimens ambiguities arise in measurement of Δx (the distance between the points corresponding to ΔT), since thermocouples and other thermometers have finite size. For these reasons, the thermal conductivity is the most difficult parameter in the thermoelectric figure of merit to measure with adequate accuracy. Because of the difficulties involved, many methods have been devised for measuring thermal conductivity. However, since thermoelectric materials have low conductivities, and since specimens available for measurement usually are quite small, only a few methods are satisfactory for use on these materials.

Measurement techniques may be classified as static or dynamic, depending on whether the temperature distribution in the specimen is time-dependent. In the following discussion, static methods will be considered first.

Static Methods. Static measurement techniques may be categorized as absolute or comparative. Absolute methods involve direct measurement of the rate at which heat enters or leaves the specimen; the usual way is to introduce heat electrically and measure the power input. In most comparative methods, the temperature difference between two points on the specimen is compared with that between points on a specimen of another material of known conductivity, with the two materials thermally in series so that the same thermal current flows through both. In some comparative measurements, the standard material is used to calibrate the apparatus in a separate experiment, rather than being placed in series with the unknown during the measurement. In general, comparative methods are preferred, since they are simpler than absolute methods and permit the use of smaller specimens. On the other hand, one absolute method is particularly useful for thermoelectric materials at moderate temperature. This method will be discussed later in this section.

1. The Cut-Bar Method—The most commonly used comparative technique is the "cut-bar" method, in which a bar or disk of the material under study and one or two similarly shaped pieces of the standard material are placed in series between a heat source and sink.[9] Fig. 5 illustrates the case in which two standard specimens are used. For accurate measurements, particularly at temperatures at which radiation is important (above about 100 to 300 degrees Kelvin, depending on the geometry and specimen conductivity), the specimens are surrounded by a guard on which a gradient is impressed by heaters to match the gradient along the specimens, in order to minimize radial heat flow. The space between the guard and specimens is evacuated or packed with insulation. At steady state, if radial heat flow is negligible (i.e., if there are no extraneous

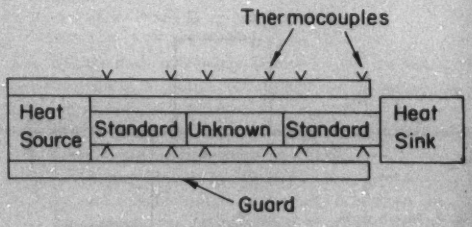


Fig. 5. Cut-bar thermal-conductivity apparatus.

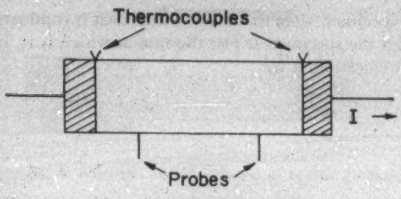


Fig. 6. Z-meter specimen.

heat gains or losses) and if the cross-sectional areas are all equal, the termal conductivity of the unknown is given by

$$\kappa = \kappa_s \frac{\Delta T_s}{\Delta T} \cdot \frac{\Delta x}{\Delta x_s}$$

where ΔT is the temperature difference between thermocouples a distance Δx apart, and the subscript s denotes the standard. With the unknown between two standards, as in Fig. 5, error from the effect of radial heat flow when a guard is not used may be reduced by averaging the two values of κ obtained by comparison with both standards, since the rate of longitudinal heat flow in the unknown is between the rates in the two standards.

As with other methods of measurement of thermal conductivity, precautions must be taken to minimize interaction of the thermometers (usually thermocouples*) with the thermal circuit under study. Thermocouple wires should be small and of low thermal conductivity to reduce heat conduction along the wires. For the same purpose, the wires should extend away from the specimen in a region as nearly isothermal as possible, that is, radially through the insulation, in the case of the cut-bar method. Further discussion of these precautions, as well as descriptions of other static measurement techniques are available.[10]

2. The Z-Meter Method—An absolute method which employs the Peltier effect to establish a temperature gradient along the specimen is particularly useful for measurements on thermoelectric materials, because of its simplicity and accuracy.[11, 12] The apparatus has become known as the Z meter, since simultaneous measurement of the three parameters in the figure of merit, i.e., the electrical resistivity and Seebeck coefficient as well as the thermal conductivity, is inherent in the measurement technique. The method has been used at temperatures from 68 to 373 degrees Kelvin and, with refinements, probably can be used over a somewhat wider temperature range.

The specimen is soldered to massive copper end caps (blocks) as discussed previously for resistivity measurements. The end caps insure that the end surfaces of the specimen are essentially isothermal and that the current density in the specimen is uniform. Thermocouples are embedded in the specimen–end cap junctions, and resistivity probes are attached to the side of the specimen. Fig. 6 illustrates the arrangement. The specimen is suspended by the wires in an evacuated chamber. If direct current is passed through the specimen by means of copper wires attached to the end caps, a temperature gradient is established as a result of the Peltier effect at the junctions. At steady state, if there are no losses (i.e., no extraneous heat transfer) it can be shown that

$$\alpha I\overline{T} = \kappa \frac{A}{L} \Delta T$$

where

α = Seebeck coefficient of the specimen relative to copper
I = current
A = cross-sectional area of specimen
L = length of specimen
ΔT = temperature difference between the thermocouples at the junctions

The potential difference between the like wires of the two thermocouples is the sum of the IR drop (across the specimen and the contact resistance at the junctions) and the Seebeck emf. On the other hand, if alternating current is passed through the specimen no Peltier effect results; thus, the potential difference between the thermocouple wires is just the IR drop. The Seebeck emf is obtained by subtraction of the a-c from the d-c potential drop. Correcting for the Seebeck coefficient of the wires and dividing by ΔT gives the Seebeck coefficient. All other quantities except κ in the equation are measureable, so κ can be calculated. The electrical resistivity is measured by means of the probes on the side of the specimen while alternating current is flowing, to avoid contact-resistance error which might result if the resistivity were calculated from the a-c IR drop between the thermocouples.

For the highest accuracy, the value obtained for κ must be corrected to account for the effects of radiation and heat flow along the wires. Since the geometry of the system is simple—involving only the specimen, wires, and end caps—a precise mathematical treatment to determine the corrections may be made.[11, 12]

Dynamic Methods. Dynamic measurement techniques are those in which the specimen temperature is a function of time as well as of position. Most dynamic methods yield values of the thermal diffusivity, a quantity related to the thermal conductivity. Diffusivity measurements will be discussed later in this section. First, two dynamic methods will be described which give

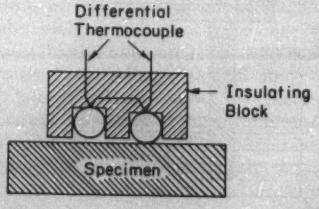


Fig. 7. Apparatus for measurement of thermal conductivity by the Powell method.

*Since the sensitivity of most thermocouples is low at temperatures below about 50 to 100 degrees Kelvin, resistance and gas thermometers are used frequently for measurements at low temperatures.

values of the thermal conductivity directly, and which are particularly useful for rapid measurements when high accuracy is not needed.

1. The Powell Method—Fig. 7 illustrates the apparatus used in the Powell method.[13] Two small metal balls are embedded in a block of insulating material. A differential thermocouple is connected between the balls. One ball protrudes slightly from the block, whereas the other is recessed slightly, so that when the block is placed on a flat specimen as shown, one ball touches the specimen and the other just misses it.

Initially, the block and specimen are separated. The block is heated to a temperature a few degrees above specimen temperature and then placed in contact with the specimen. The ball which touches the specimen loses heat by conduction into the specimen, by radiation, and, if the apparatus is not evacuated, by conduction and convection through the atmosphere. The other ball loses heat by all of these processes except conduction into the specimen. Hence, a time-dependent temperature difference, ΔT, develops between the balls. The rate at which ΔT increases is essentially a function only of the geometry and properties of the specimen and balls, since the effects on ΔT of the undesired heat-transfer processes (i.e., all except conduction into the specimen) are largely self-canceling.

Empirically, it is found that a plot of the square root of thermal conductivity against the rate of change of ΔT is a straight line for materials with a wide range of conductivity. Powell obtained anomalous results for lead, presumably because the contact area was atypical as a result of the softness of the metal. However, for a large group of other materials, including metals and insulators, values of thermal conductivity obtained agreed with known values within a few per cent.

2. The Ioffe Method—Another dynamic technique for direct measurement of thermal conductivity is used by A. F. Ioffe and co-workers for rapid measurements on semiconductors in the vicinity of room temperature.[14-17] The method is illustrated in Fig. 8.

The specimen is in contact with a massive copper block and a copper rod, as shown in the figure. Initially, this assembly is at room temperature. Then the end of the copper rod is immersed in ice water, and the temperature at the specimen-block junction is measured as a function of time. If there are no losses, and if the total heat capacity of the block is much greater than that of the specimen, then the rate at which heat is conducted through the specimen is just the rate at which it is lost by the block. That is,

$$\kappa \frac{A}{L} \Delta T = -C \frac{dT}{dt}$$

where

C = total heat capacity of the block

$\frac{dT}{dt}$ = rate of temperature change of the junction

A correction must be made if the total heat capacity of the specimen is not negligible compared with that of the block. In this case, since the junction temperature, and therefore the mean specimen temperature, changes with time, part of the heat conducted through the specimen is for cooling of the specimen itself. Although the correction term in the equation involves the heat capacity of the specimen, the term usually is not large, so that an accurate value of the heat capacity is not required.

In this method as used by Ioffe and co-workers, the equipment is not evacuated, there is no guard to reduce radiation effects, and thermal contact is made between the specimen and the copper with oil rather than with a solder. Corrections can be made for errors from these sources. With sacrifice in speed of operation, the apparatus can be modified to reduce such errors and to permit use of the technique over a range of temperature.

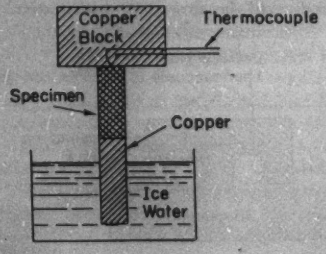


Fig. 8. Apparatus for measurement of thermal conductivity by the Ioffe method.

3. Thermal-Diffusivity Measurement Methods—If the heat flow in a homogeneous, isotropic solid is not in steady state, so that the temperature is time-dependent, the rate at which heat enters a volume element is not the same as the rate at which it leaves. In this case, the continuity equation becomes

$$c \frac{\partial T}{\partial t} = -\nabla \cdot \vec{q}$$

where

c = specific heat per unit volume

$\partial T/\partial t$ = time rate of change of temperature of the volume element

$\vec{q}$ = rate of transfer of heat per unit area

If transfer by radiation can be neglected, so that

$$\vec{q} = -\kappa \nabla T$$

and if κ and c are independent of temperature, the equation reduces to

$$\frac{\partial T}{\partial t} = D \nabla^2 T$$

where $D = \kappa/c$ is called the thermal diffusivity of the medium. It may be seen that the equation is formally similar to the equation for mass transport by diffusion. The constant D has the dimensions l^2t^{-1} of a diffusion coefficient.

Thermal diffusivity is measured by nonsteady-state methods. The usual techniques employ heating with a periodically varying power input, although transients

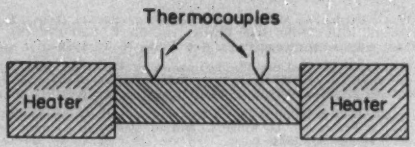


Fig. 9. Apparatus for measurement of Seebeck coefficient.

may be used. Diffusivity measurements have the disadvantage that the specific heat per unit volume must be known to obtain the thermal conductivity. This failing is counterbalanced by the fact that extraneous heat transfer has less effect on the accuracy of the measurements than on direct measurements of thermal conductivity. Hence, diffusivity measurements are particularly useful at high temperatures, where radiation is important.

If the temperature of a point in a solid material is made to vary periodically, a periodic temperature wave moves through the material with velocity v. In the simple case of purely longitudinal flow along an infinitely long rod, with a sinusoidal temperature wave, $T = A \sin \omega t$, where A and ω are the amplitude and angular frequency, it can be shown that the diffusivity is given by $D = v^2/2\omega$. The diffusivity also may be determined from the attentuation of the wave as it moves along the rod from the relation

$$D = \frac{\omega}{2}\left(\frac{d}{\ln \frac{A_2}{A_1}}\right)$$

where d is the distance between two points with amplitudes A_1 and A_2. Thus, measurements of velocity and attenuation of the wave give independent checks on the value of D.

The conditions outlined in the foregoing usually are not met in practice. Extraneous heat flow must be accounted for, although in some cases this is less difficult than with direct measurements of thermal conductivity. Also, nonsinusoidal wave forms are sometimes used. Actual measurement techniques in use will not be discussed here; the reader is referred to more detailed accounts for additional information.[18-20] A method employing radiant heating is of particular interest for measurements on small specimens of semiconductors.[19]

SEEBECK COEFFICIENT

If two dissimilar conductors (A and B) are joined at both ends and if the junctions are maintained at different temperatures (T_1 and T_2), a potential difference V exists between the junctions. The Seebeck coefficient (thermoelectric power) of A relative to B is defined as

$$\alpha_{AB} = \lim_{T_1 - T_2 \to 0} \left(\frac{V}{T_1 - T_2}\right)$$

The convention will be used here that α_{AB} is positive if the conventional electric current flows from B to A at the cold junction, although there is not agreement on the sign convention in the literature. The absolute Seebeck coefficient α of a single material is defined in terms of another thermoelectric parameter, the Thompson coefficient. However, for present purposes it is adequate to say that the absolute Seebeck coefficient of a material is its coefficient relative to a superconductor, for which α is zero. In line with the sign convention given above, $\alpha_{AB} = \alpha_B - \alpha_A$.

Determination of the Seebeck coefficient involves measurement of the temperature and potential differences between two points on a specimen. The measurement can be made concurrently with the measurement

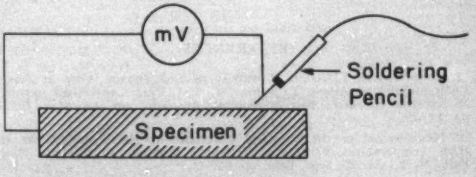


Fig. 10. Hot-probe apparatus for determining the sign of the Seebeck coefficient.

of thermal conductivity by a static method such as the cut-bar technique. As in measurement of thermal conductivity, care must be taken to insure that the temperature of a thermocouple* is the same as the specimen temperature at the point of contact. If there is thermal resistance at the specimen–thermocouple junction, and if there is heat flow along the thermocouple wire, there will be a temperature difference across the junction. Hence, apparatus should be well insulated, small wires should be used, and the section of wire at the specimen should be as near isothermal as possible. Further discussion of these details and reference to measurement of the Seebeck coefficient of several semiconductors are given elsewhere.[21]

A simple apparatus for measurement of the Seebeck coefficient over a wide temperature range is shown in Fig. 9. The specimen is fastened between two small resistance heaters by soldering or by clamping. Thermocouples are soldered or welded to the side of the specimen. The apparatus is held in an evacuated or insulation-packed tube which is immersed in a cooling bath or heated in a furnace. The two heaters have independent current supplies, and are used both for establishing a gradient and for controlling the mean specimen temperature.

If contacts of low thermal resistance can be made to the material under study, the thermocouples may be attached to metallic blocks containing the heaters, so that it is unnecessary to solder to the specimens.[22] In this case, care must be taken to insure that there is negligible temperature drop between the thermocouple bead and the end of the block contacting the specimen.

*As with thermal conductivity measurements, other thermometers sometimes are used at low temperatures.

Frequently it is desired to determine the sign of the Seebeck coefficient quickly, without measuring its value. The "hot probe" method,[7] a simple technique for this, is illustrated in Fig. 10. One terminal of a galvanometer or a center-zero microammeter is connected to a soldering pencil or other small heat source. The other terminal is connected to the specimen. When the pencil is touched to the specimen, the direction of deflection of the meter movement indicates the sign of the thermal emf. The hot probe is positive or negative for negative or positive value of α, respectively. The apparatus also may be used to test the homogeneity of semiconductor specimens and to detect p-n junctions.

REFERENCES

1. Anisotropy of Electrical Resistivity of Cold-Drawn Wires of Some Cubic Metals and Alloys, T. Brown, W. T. Clothier. *Australian Journal of Scientific Research*, East Melbourne, Australia, vol. A5, Mar. 1952, pp. 119-27.

2. Measurement of the Electrical Resistance of Metals and Alloys at High Temperatures, P. Chiotti. *Review of Scientific Instruments*, New York, N. Y., vol. 25, Sept. 1954, pp. 876-83.

3. Apparatus for Measuring Resistivity and Hall Coefficient of Semiconductors, T. M. Dauphinee, E. Mooser. *Ibid.*, vol. 26, July 1955, pp. 660-64.

4. Low-Level Thermocouple Amplifier and a Temperature Regulation System, T. M. Dauphinee, S. B. Woods. *Ibid.*, pp. 693-95.

5. Note on Measurement of Figure of Merit of Thermoplastic Materials, W. C. Myers, R. T. Bate. *Ibid.*, vol. 31, Apr. 1960.

6. Resistivity Measurements on Germanium for Transistors, L. B. Valdes. *Proceedings*, Institute of Radio Engineers, New York, N. Y., vol. 42, Feb. 1954, pp. 420-27.

7. W. C. Dunlap, in Methods of Experimental Physics (book), L. Marton, general editor: Solid State Physics, vol. 6B. K. Lark-Horovitz, V. A. Johnson, editors. Academic Press, New York, N. Y., 1959.

8. Contactless Method for the Estimation of Resistivity and Lifetime of Semiconductors, H. K. Henisch, J. Zucker. *Review of Scientific Instruments*, vol. 27, June 1956, pp. 409-10.

9. Apparatus for Determining Thermal Conductivity by Comparative Method, J. Francl, W. D. Kingery. *Journal*, American Ceramic Society, Easton, Pa., vol. 37, 1954, p. 80.

10. High-Temperature Technology (book), I. E. Campbell, editor. John Wiley & Sons, Inc., New York, N. Y., 1956, pp. 429-46.

11. Measurement of Thermal Conductivity by Utilization of the Peltier Effect, T. C. Harman, J. H. Cahn, M. J. Logan. *Journal of Applied Physics*, New York, N. Y., vol. 30, 1959, pp. 1351-59.

12. M. A. Kaganov, I. S. Lisker, I. G. Mushkin. *Zhurnal Tekhnicheskoi Fiziki*, Moscow, USSR, vol. 29, 1959, p. 988; *Soviet Physics—Technical Physics*, New York, N.Y., vol. 5, 1960, p. 905.

13. Experiments Using Simple Thermal Comparator, R. W. Powell. *Journal of Scientific Instruments*, London, England, vol. 34, Dec. 1957, pp. 485-92.

14. A. F. Ioffe, A. V. Ioffe. *Zhurnal Tekhnicheskoi Fiziki*, vol. 28, 1958, p. 2357; *Soviet Physics—Technical Physics;* vol. 3, 1958, p. 2163.

15. M. A. Kaganov. *Ibid.*, p. 2169; *Soviet Physics—Technical Physics*, p. 2169.

16. Theory of the A. F. Joffe Method for Rapid Measurement of the Thermal Conductivity of Solids, W. F. G. Swann. *Journal*, Franklin Institute, Philadelphia, Pa., vol. 267, 1959, pp. 363-80.

17. Concerning Thermal Junction Resistance in the A. F. Joffe Method for Measurement of Thermal Conductivity, W. F. G. Swann. *Ibid.*, vol. 268, 1959, pp. 294-96.

18. Thermal Diffusivity of Metals at High Temperatures, P. H. Sidles, G. C. Danielson. *Journal of Applied Physics*, vol. 25, 1954, pp. 58-66.

19. Measurement of Thermal Diffusivity in Semiconductors: InSb and Mg_2Sn, I. I. Sochard, J. H. Becker. *Bulletin*, American Physical Society, New York, N. Y., series II, vol. 4, 1959, p. 134.

20. N. Pearlman, in Methods of Experimental Physics (book), *op. cit.*: Solid State Physics, vol. 6A.

21. H. P. R. Frederikse, V. A. Johnson, and W. W. Scanlon, in Methods of Experimental Physics (book), *op. cit.*: Solid State Physics, vol. 6B.

22. Semiconductor Thermoelements and Thermoelectric Cooling (book), A. F. Ioffe. Infosearch, Ltd., London, England, 1957, p. 132.

THERMOELECTRICITY

A Thermoelectric Refrigerating System for Submarines

R. G. SICKERT

An investigation for determining the feasibility of this system is divided into three phases: (1) general investigation of cooling capacity and performance of thermoelectric couples; (2) design of a refrigerating system for a large frozen stores room and a smaller chilled stores room; and (3) determination of the performance and operation of the entire system.

IN April of 1959, the Whirlpool Corporation was asked by the Bureau of Ships, U. S. Navy, to determine the feasibility of installing a thermoelectric refrigerating system for preservation of foodstuffs on a nuclear submarine. Particular emphasis was to be placed on optimization of all facets of the performance of the system and the reliability of the system under extended operation.

The direct problem as set forth by the Navy was to supply the cooling requirements for two food storage rooms; one which must hold frozen stores at 0 F and another which must maintain chilled stores at 33 F. The smaller room, however, must be capable of maintaining 0 F when required to handle additional frozen stores at the outset of a cruise.

In many respects, the thermoelectric system must be capable of performing under the same conditions as the conventional compression system now in use. The

A special article recommended for publication by the AIEE Solid State Devices Committee.

R. G. Sickert is with the Whirlpool Corporation, St. Joseph, Mo.

The work on this system is being conducted under the auspices of the Bureau of Ships, U. S. Navy Contract NObs-77128

most important carry over from the compression system is that the heat rejected by the thermoelectric system is removed at 55 F by return water from the air-conditioning system. This means that the ultimate temperature difference between which the thermoelectric system must work is well within the capabilities of Peltier materials available today.

The actual investigation as carried on by the Whirlpool Corporation was divided into three phases: (1) a general investigation of the performance and capacity of thermoelectric cooling systems was performed; (2) the best system design was established; and (3) the operation of this system was defined. The balance of this article will be devoted to the findings in each phase of activity.

PHASE I—GENERAL INVESTIGATION

In order to describe the performance and operation of a Peltier cooling system, the basic relations derived by Altenkirch[1] governing the net rate of heat removal from a body and the coefficient of performance of that system must be reviewed.

The net rate of heat removal of an idealized thermoelectric cooling couple composed of positive- and negative-type thermoelectric legs may be written as follows

$$Q = (S_p - S_n)\, T_c I - \tfrac{1}{2} I^2 R - K\,(T_h - T_c) \qquad (1)$$

where:

Q = the net rate of heat removal, watts
S = the Seebeck coefficients of the two legs of the couple designated by the subscripts p and n, volts per degree C
I = the direct current flowing in the circuit, amperes
R = the total resistance of the two legs, ohms
K = the thermal conductance of the two legs, watts per degree C
T_h = the hot-junction temperature, degrees K
T_c = the cold-junction temperature, degrees K

If the loss due to junction or contact resistance between the thermoelectric materials and electric conductors is included, equation 1 becomes

$$Q = (S_p - S_n)\, T_c I - \tfrac{1}{2} I^2 R - K\,(T_h - T_c) - 2 I^2 R_j \qquad (2)$$

where

R_j = the resistance of one junction, ohms

It is assumed that all four (two cold and two hot) junction resistances are equal.

The effect of ripple in the direct current, defined as the ratio of the rms value of the a-c component divided by the average d-c level, may be included in the basic cooling equation as follows:

$$Q = (S_p - S_n)\, T_c I - \tfrac{1}{2} I^2 R\,(1 + \phi^2) - 2 I^2 R_j\,(1 + \phi^2) - K(T_h - T_c) \qquad (3)$$

where

ϕ = current ripple, dimensionless

The power input in watts to obtain this rate of cooling may be found in a similar manner and is

$$W = (S_p - S_n)\,(T_h - T_c)\, I + I^2 R\,(1 + \phi^2) + 4 I^2 R_j\,(1 + \phi^2) \qquad (4)$$

The coefficient of performance (COP) of the system, therefore, is

$$\text{COP} = \frac{Q}{W} \qquad (5)$$

To increase the utility of equations 3 and 4 the electrical resistance and thermal conductance of the thermoelectric legs may be written in terms of the specific electrical resistivity, thermal conductivity, and the configuration of each leg.

The resistance term, therefore, may be written as

$$R = \rho_p\,(l/A_p) + \rho_n\,(l/A_n) \qquad (6)$$

where

ρ = electrical resistivity of each leg, ohm-cm
l = leg length, cm
A = leg area, cm²

The thermal conductance term may also be written as

$$K = k_p\,(l/A_p)^{-1} + k_n\,(l/A_n)^{-1} \qquad (7)$$

where

k = thermal conductivity of each leg, watts per cm per degree C

Assuming equal lengths of the p- and n-type legs and the ratio

$$A_p/A_n = (k_n\,\rho_p/k_p\,\rho_n)^{\frac{1}{2}} = M \qquad (8)$$

It is possible to optimize the COP based on the proper proportioning of the areas of the two legs of the couple.

By expanding Q and W in terms of the specific material properties and areas (leg lengths assumed equal) and using $A_p = A_n M$, the COP may be written as

$$\text{COP} = \frac{(S_p - S_n)\, T_c I - \tfrac{1}{2} I^2\,(1+\phi^2)\,(l/A_n)\,(\rho_p M^{-1} + \rho_n) - 2 I^2 R_j\,(1+\phi^2) - (l/A_n)^{-1}\,(k_p M + k_n)\,(T_h - T_c)}{(S_p - S_n)\,(T_h - T_c)\, I + I^2\,(1+\phi^2)\,(l/A_n)\,(\rho_p M^{-1} + \rho_n) + 4 I^2 R_j\,(1+\phi^2)} \qquad (9)$$

By taking the partial differential of COP with respect to l/A_n, the configuration of the n-type leg, and equating it to zero, the l/A_n ratio may be obtained which will give the maximum COP.

At this point, it is possible to describe completely the optimized performance of a thermoelectric couple in terms of the operating current I; the temperatures T_h and T_c; the material parameters S, ρ, and k; power supply ripple ϕ; and the contact resistance R_j.

The selection of thermoelectric material parameters for use in this study was based on the figure of merit or Z value derived by Ioffe.[2] For a thermoelectric couple this value may be written as

$$Z = (S_p - S_n)^2\,[(k_p\,\rho_p)^{\frac{1}{2}} + (k_n\,\rho_n)^{\frac{1}{2}}]^{-2} \qquad (10)$$

It is an effective measure of the quality of a thermoelectric material, and in the ideal case, the figure of merit and operating temperatures determine the optimum COP of the idealized couple.

The refrigerating capacity, equation 3, is determined not only by the figure of merit and temperatures but also by the makeup of the thermoelectric parameters to

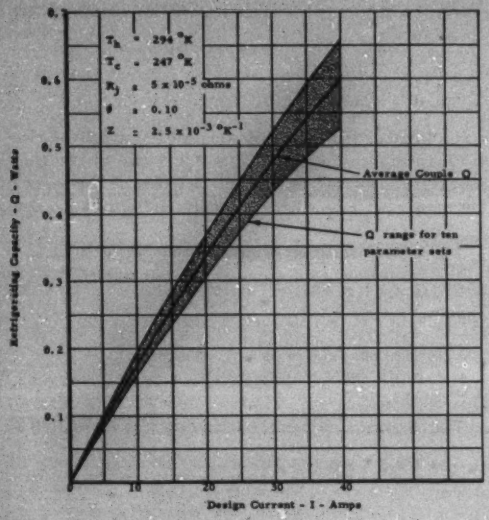


Fig. 1. Refrigerating capacity per couple at maximum COP for various thermoelectric properties and design currents.

give a particular figure of merit. Because of this fact, a large range of values for each material parameter was selected based on known variations of each parameter. The figure of merit, equation 10, was then calculated for each combination of material parameters using an IBM *650* digital computer with the output limited to a figure of merit falling between 2.5 and 2.6 $\times$ 10^{-3} per degree K. This narrow range of figure of merit was selected as thermoelectric material of this quality level is readily available at present.

To evaluate the performance of various combinations of thermoelectric materials in couple form, the operating temperatures were established as single values. The hot-junction temperature T_h, was set at 70 F (294 K) and the cold-junction temperature T_c at —15 F (247 K). These temperatures contain a 15 F adjustment for thermal losses in the heat transfer systems of the ultimate thermoelectric module design at both the hot and cold junctions. In other words, heat is rejected to a 55 F water sink (70 F hot-junction temperature) and absorbed from a 0 F air source (—15 F cold-junction temperature).

An entire series of calculations of Q, W, and COP at the optimized condition was then performed with a range of design currents, junction resistances, and power supply ripple values for each parameter set used. The typical results of such a calculation for 10 sets of thermoelectric material parameters are shown on Figs. 1, 2, and 3.

The vertical range of each curve at any specific design current illustrates the effect of material parameter variation on the optimized quantity. For example, Fig. 1 shows that Q varies from 0.31 to 0.37 watts at the design current of 20 amperes. This illustrates the maximum and minimum values of Q produced by the 10 material parameter sets, each optimized individually. The range indicated on Fig. 1 does not completely describe the possible variation of Q as different parameter sets of the same Z range could produce values above and below the curve limits.

Fig. 3 indicates that the COP covers a range of values at a specific design current and also falls off as the design current is increased. The former effect is caused by the use of material parameters producing a figure of merit falling between 2.5 and 2.6 $\times$ 10^{-3} per degree K. If a single value of Z were used, rather than a range, the COP would be a point function at any design current. The reduction in COP as the design current is increased is caused by using a constant junction resistance through the range of design inputs. The underlying assumption in this case is that thermoelectric leg area is held constant for all design values.

The previous discussion has been based on the operation of thermoelectric couples whose material parameter makeup results in differing Q, W, and COP values over a fixed range of temperature. For system design where a large number of couples are used, it is desirable to reduce the variations to single valued functions for ease in calculation.

Assuming a panel of 10 thermoelectric couples is to be made with the material parameter sets used to define

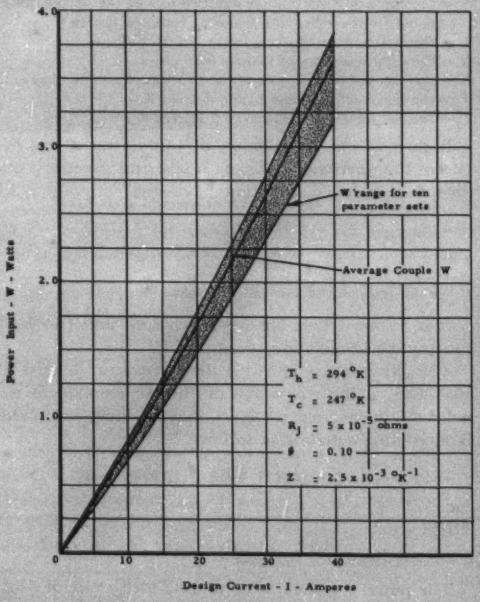


Fig. 2. Power input per couple at maximum COP for various thermoelectric properties and design currents.

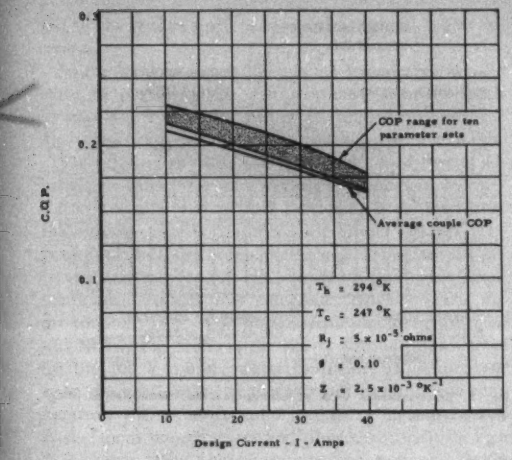


Fig. 3. Maximum coefficient of performance for various thermoelectric properties and design currents.

Figs. 1, 2, and 3, the total amount of heat absorbed at a constant temperature is the summation of Q for each thermoelectric couple. A similar summation applies to W. In order to reduce the performance of this arbitrary panel to a "per couple basis," the gross amount of heat absorbed is divided by the number of couples used. The result, therefore, is an average Q for a typical couple in the system. Examination of equations 3 and 4 shows that this may be accomplished simply by averaging the material parameters. The result of such an action is indicated on Figs. 1, 2, and 3 by the single solid lines. This permits design of a complete system to be based on an average of material parameters obtained from a statistical lot sample.

Figure 3 is of particular interest as the use of average material parameters caused the COP to fall below the band for the individual parameter systems. This effect is produced by the use of a single l/A_n which optimizes the system rather than individual components in the system. In other words, the l/A_n value used for all couples in the averaged system does not optimize the performance of each individual couple but does optimize the over-all performance of the system.

A further modification in calculation that must be made for ease of manufacture is determination of a single l/A value for both p-type and n-type material. This, of course, can only reduce the performance of a system.

As previously stated, in order to optimize the COP and refrigerating capacity Q, it is necessary that the relationship shown by equation 8 exist. However, if both materials have the same diameter, the area ratio, A_p/A_n must equal 1. Therefore, M in equation 9 must be dropped and A_n must be replaced by A, since $A_n = A_p$. Fig. 4 shows the loss from optimum design caused by allowing A_n to equal A_p without regard to the optimum area ratio prescribed by M. The majority of thermoelectric materials tested indicate the value of M will fall between 0.8 and 1.2 which produces a loss from optimum COP or Q of less than 3%.

The actual system design described further in this article is based on the single l/A design. This produces what is felt to be the optimum practical design.

PHASE II—SYSTEM DESIGN

With the design method established as outlined in the previous section, it became necessary to establish single values for the variables shown in equations 3 and 4 to produce operation systems.

The material parameters used in the design calculation, which are the averages of the 10 selected parameter sets used previously, are as follows:

$(S_p - S_n) = 385 \times 10^{-6}$ volts per degree C
$\rho_p = 0.76 \times 10^{-3}$ ohm-cm
$\rho_n = 0.88 \times 10^{-3}$ ohm-cm
$k_p = 0.0186$ watt per degree C
$k_n = 0.0178$ watt per degree C
$Z = 2.503 \times 10^{-3}$ per degree K

The junction resistance, established through measurement of typical couples was found to average 5×10^{-5} ohms. As the power available for operation of the refrigerating system will be 3-phase 60-cycle a-c rectified to d-c, a rather conservative ripple factor of 10% was selected. The operating temperatures of the thermoelectric panel remained at 70 F and —15 F for T_h and T_c respectively.

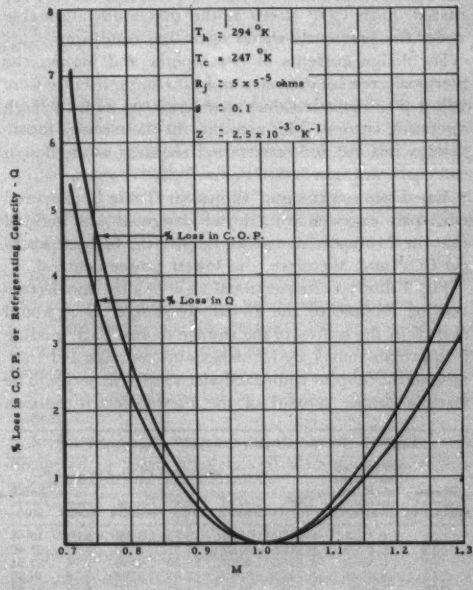


Fig. 4. Effect of variation in M with $A_p/A_n = 1$ on COP and refrigerating capacity.

A review of possible location of the thermoelectric cooling units showed the ceiling of both storage rooms to be preferred. The reasons for this selection are: (1) availability of large area for the air-side heat-transfer surfaces; (2) relatively easy accessibility for servicing; and (3) availability of adequate means of mounting.

Heat load calculations for the frozen and chilled stores rooms at 0 F internal air temperature were based on the dimensions of the storage rooms for the *SS(N) 593* submarine in accordance with U.S. Navy specifications DDS 59-2. An agreement with Bureau of Ships allowed for normal system operation on a 24-hour-per-day basis with an additional 20% allowance for excess cooling capacity. Because the thermoelectric cooling panel design calls for close spacing of the heat absorbing and dissipating surfaces, it was necessary to adjust the heat loss through the ceilings of the rooms. Thus, the thickness of insulation in the thermoelectric modules was very thin compared to the original ceiling insulation thickness, which resulted in increased over-all heat losses.

After allowing for the added heat loss through the modules, the space between the modules, fasteners, etc.; the refrigerating capacity requirements were calculated for a 20-ampere thermoelectric design current. The frozen stores room heat load at 0 F was found to be 9,068 Btu per hour (2,660 watts) and the chilled stores room heat load at 0 F was 3,990 Btu per hour (1,170 watts). The number of couples and power required for a number of design currents using these fixed loads are shown in Table I. All power requirements are for direct current; losses in transformers and rectifiers are not included. Each COP stated is the maximum attainable under the previously stated operating conditions.

For design currents of 50 amperes and higher, the thermoelectric leg diameter and junction resistance were adjusted to realistic values commensurate with the high operating current. This accounts for the seeming inconsistency in COP and total power required as the design current is increased.

Based on information shown in Table I tempered with past experience in device design, it was decided that the 20-ampere design would give the highest practical COP and, therefore, the lowest power demand.

Fig. 5 shows a cross-sectional view of a thermoelectric-cooling module of the 20-ampere design as it would appear in the ceiling of the storage rooms. Each module is approximately 7 by 13 inches and contains 144 thermoelectric couples connected electrically in series. The module proper consists of the thermoelectric portion

Table I. Power Requirement* — Normal Load

Design Current (amperes)	Refrig. Cap. per couple at design current (watts)	COP	Frozen Stores 0 F		Chilled Stores 0 F		Total Power (kw)
			No. of couples	Power (kw)	No. of couples	Power (kw)	
20	0.3354	0.1950	7920	13.64	3490	6.00	19.64
30	0.4769	0.1791	5580	14.87	2450	6.53	21.40
40	0.6005	0.1641	4430	16.20	1950	7.14	23.34
50	0.8599	0.2033	3092	13.09	1360	5.76	18.85
100	1.5898	0.1791	1675	14.81	738	6.53	21.34
150	2.1848	0.1568	1218	16.95	536	7.46	24.41

*Power is based on maximum demand for the conditions listed.

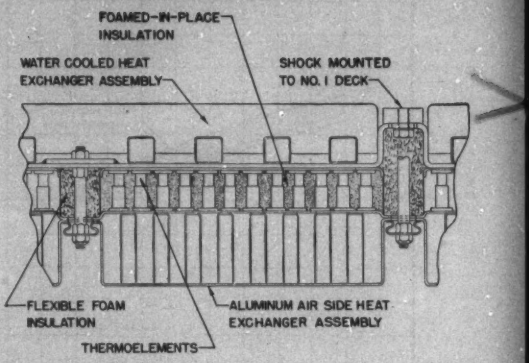


Fig. 5. Cross-sectional view of ceiling-mounted thermoelectric refrigerating system.

and an air-side heat exchanger which is finned and formed into a duct. The lower assembly transfers room heat to the thermoelectric system. The heat exchanger plate, to which the module is held, is formed with passages for circulating cooling water to remove heat rejected from the system.

Each room uses the same size cooling module for reasons of simplicity and interchangeability. However, the arrangements in each room are different. The frozen stores room, which is the larger room, uses 54 modules arranged in 9 rows of 6 modules each. As indicated in Fig. 5, the modules are lined up lengthwise to provide a long, continuous air duct. The smaller chilled stores room refrigeration system is assembled in the same manner except six rows of four modules each are used.

The specifications set forth by the Navy state that the chilled stores room must be operable at either 0 F or 33 F. To operate the chilled stores room at 33 F with the couples sized for the more severe 0 F condition, it becomes necessary to reduce the operating current. Calculations show that the operating current drops from 20 to 9.2 amperes while the COP increases from 0.19 to 0.61. Under this condition, with the frozen stores room at 0 F and the chilled stores room at 33 F, the total system power requirement drops from 19.6 kw to 15 kw.

In order to meet pulldown load conditions, it is necessary to operate at a current higher than the optimized design current. In this case, the cooling capacity per couple is increased from 0.3354 watt (Fig. 5) to 0.435 watt. The maximum power demand under the pulldown load conditions for both rooms, therefore, becomes 21.5 kw for the 20-ampere design.

PHASE III—OPERATION OF THE SYSTEM

THE DESIGN of the system and performance figures just discussed are based on 20% excess cooling capacity in the thermoelectric cooling system. This figure, of course, was added to allow a margin of safety for operation under emergency conditions where cooling modules

fail or the temperature of the cooling or sink water increases.

In the latter case, a study was made to determine the effect of operating the refrigeration system for both rooms with 100 F sink water circulating in the heat dissipation system rather than the normal 55 F water.

To accomplish this, the room heat loads were adjusted to reflect the new conditions and the thermoelectric cooling system was recalculated to determine the cooling capacity of the modules under the new temperature conditions using the former 20-ampere design. It was determined that the minimum attainable room temperature under this emergency condition was approximately 18 F. The power requirement in this case was 38 kw. Fig. 6 shows the power consumption curves for the 100 F cooling water condition. It is apparent from the curve shape that a sacrifice in minimum temperature will produce considerable savings in power. If the room temperatures are allowed to reach 20 F, a 2 F change from the minimum condition, the power required drops to 29.5 kw, a saving of approximately 22%.

The curves shown in Fig. 6 indicate that room air temperature rises with an increase in power after reaching a minimum. At the minimum air temperature, the thermoelectric system is operating at maximum refrigerating capacity. An increase in power beyond this point causes an increase in I^2R losses in the thermoelectric couples which reduces the net refrigerating effect of the system and, therefore, increases room air temperature.

While these calculations were made under the assumption that both rooms would maintain identical temperatures, the data may be used to estimate power requirements with both rooms operating at different temperatures. The maximum error involved if an air temperature difference between rooms of 33 F exists is less than 5%.

Effect of Module Failure. Because of the 20% excess capacity in the system design, a number of module failures under normal operating conditions may be tolerated. If a module fails, the room heat load increases due to the backflow of heat through the thermoelectric legs. During periods of module operation, this heat leak is accounted for in the design calculation (last term of equation 3) and is not part of the effective room heat load.

Fig. 7 indicates expected operation of the frozen stores room under various modes of operation and with modules inoperative. If the cooling system is functioning normally, the minimum room temperature attainable is approximately —8 F at an input level of approximately 30 amperes. Under normal conditions, the room temperature can be maintained at 0 F at an input of approximately 19 amperes. If the 0 F air temperature line is followed vertically, it is evident that a room temperature of 0 F may be held with eight modules inoperative. The power requirement, however, increases from 12 kw to 16 kw in this case, because the input

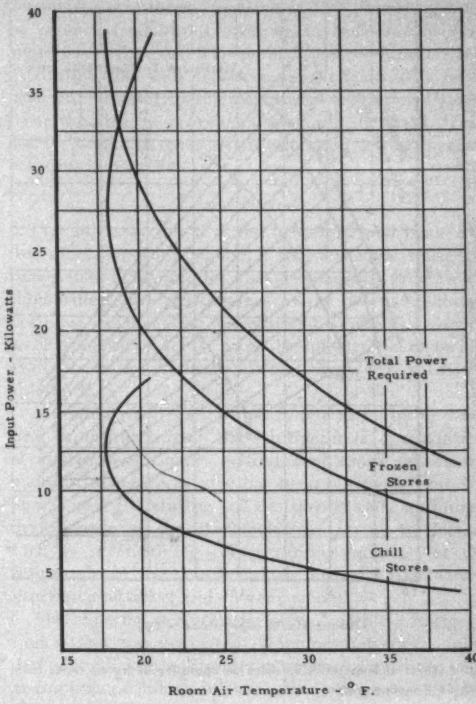


Fig. 6. Power requirements vs. room air temperature with 100 F cooling water.

current must be raised to approximately 30 amperes to handle the heat load.

A similar analysis was performed for the smaller chilled stores room which indicated three module failures would not increase the room temperature above 0 F. The power requirement in this case increased from 5 kw at normal operation to 8 kw.

Power Supply and Control System. The general objectives for the control and power supply system are:

1. The thermoelectric refrigerating system will be designed to operate from a 3-phase 60-cycle power supply.

2. The controls should be as simple as possible for operation.

3. There should be a means of readily detecting any deviation of room temperature from a predetermined range.

4. There should be a method of easily determining and bypassing any module failures.

The thermoelectric system requires direct current for operation; therefore, the 3-phase current can be rectified in a full-wave bridge to obtain direct current with a low-percentage ripple. Since a-c power is much easier

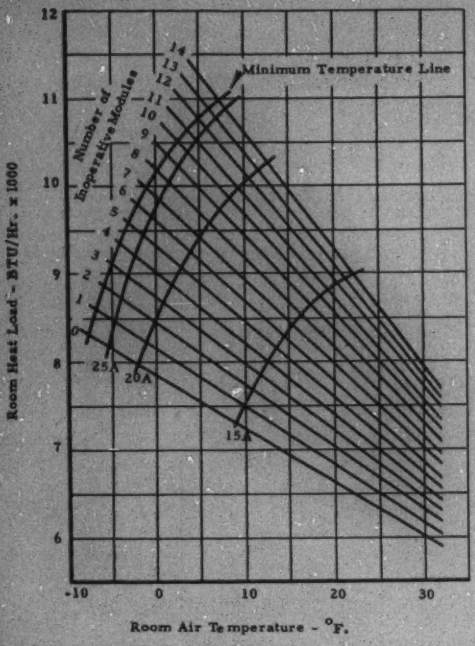


Fig. 7. Effect of inoperative modules on operation of frozen stores room with 55 F cooling water.

to vary than d-c power without creating unnecessary losses, control should be accomplished prior to rectification.

As the heat loads in each room will remain reasonably constant for the majority of operating time, a manual variable transformer has been suggested as a means of control. This is one of the simplest methods of control if loads remain constant as the cooling capacity of the thermoelectric system remains constant at a preset power input level. Although the following information was developed for a manual system, it can easily be converted to automatic operation. The actual power supply system to be used in this case is dependent upon the type of wiring network for each room. This, in turn, depends upon the effect of inoperative modules in the system.

It is desirable to place as many modules as possible in series to keep current requirements as low as possible. However, an interruption of current in a series circuit by the failure of a single thermoelectric couple would render all the modules in it ineffective until repairs have been made. For manual control, the remaining parallel circuits would continue to operate at the same current until a manual change is made. Based on the number of tolerable module failures and mounting configuration, it has been determined that the wiring network for the chilled stores room should consist of four modules in series and six parallel circuits. The frozen stores room wiring should consist of six modules in series and nine parallel circuits.

With this wiring network, a single series circuit failure would allow the chilled stores room to reach 10 F if the normal input is set for 0 F operation and the current is not changed. A maximum of 38 F would be reached if a series circuit fails while the room is operating at 33 F.

In the frozen stores room, a single series circuit failure would cause the room temperature to reach 6 F. This, however, can be returned to 0 F operation by increasing the power input to the refrigerating system.

Since any module failure requires an increase in power demand, and 0 F cannot be maintained in either room with more than one series circuit failure, it is necessary to provide a means of repair or bypass so a single failure does not permanently affect the continuity of the whole circuit. Since the modules would not readily be accessible due to food loads in each room, tap leads from each module will be brought out to a patch panel external to each room. These leads permit temporary bypassing of inoperative modules and allow operation of remaining modules in the series circuit until the defective unit can be replaced. The modules in any given series circuit will be dispersed about the room rather than mounted in a row so that "hot spots" will not occur due to a concentration of inoperative modules in any given air duct. Circuit loops can be connected such that magnetic fields produced by one circuit would be cancelled by another circuit, thereby keeping the net magnetic field to a minimum.

After the wiring circuits have been established for each room, the power supply requirements may be determined.

Either a single variable transformer for each room or one for each series circuit could be used. A variable transformer for each room would require nearly balanced parallel circuits for the best operation. Therefore, it would be necessary to replace any inoperative modules with a dummy load so the remaining modules in the series circuit would operate at the same current as the rest of the modules in the room. A single variable transformer for each room would be extremely simple for operator control, since there is only one setting to make for a given heat-load condition.

The alternate to a single variable transformer for each circuit requires nine variable transformers for the frozen stores room and six variable transformers for the chilled stores room. Since each circuit is individually controlled, inoperative modules can be shorted out and the voltage input reduced to maintain the desired current. All of the transformers for one room would be set so that nearly the same current flows in each circuit. For small changes in load, only the lowest or highest currents would be changed to obtain the equilibrium. For large changes in load, or a marked deviation in room temperature, each input would be changed to a new level. Closer adjustment of the bal-

anced input would be possible with individual circuit control over that of the single-input parallel-circuit alternative.

Although the systems described would provide a unit operating with a minimum power input, the use of a system employing a combination of current level switching with a variable transformer would reduce the over-all weight and size of the power supply system. Only one third of the thermoelectric modules would be proportionally controlled while the remaining units would operate from one of three constant voltage levels. The voltage level would be chosen to meet the load requirements and would be a coarse adjustment of the cooling capacity. The proportionally controlled modules would serve as fine adjustment on the cooling rate.

Although the current levels can be obtained through parallel-series switches, a transformer tap system would be preferable. Since it will be necessary to install a transformer to reduce the 440 volts to an operating voltage, taps could be used on this transformer. A manual switch would be used to select the transformer tap for a high, medium, or low rate of cooling.

An indicator and warning system to indicate abnormal operation of the system and to assist in trouble shooting is required for efficient operation. A method has been devised to do this very simply by placing an indicator light in parallel with each module. These indicator lights will be placed on a panel adjacent to the two rooms. During normal operation at 20 amperes, the voltage across each module is approximately 12 volts. Any open circuit within the module would result in a voltage rise across the module and the lamp to the voltage level across the whole series circuit. As the current would be very low because of the relatively high resistance of the indicator lamp, the light would brighten for that particular inoperative module; therefore, it can be easily determined which module should be bypassed.

Bypassing of the module can then be effected at the indicating panel. The bypassing element will be placed in parallel with the lamp or may be used in place of the lamp. If the operating voltage of the module is great enough, the indicator would glow faintly during normal operation, light brightly for an open-circuit condition, or extinguish for a short circuit across the module. The remaining lamps in the circuit would glow faintly, extinguish, and brighten slightly for the respective conditions. As the load decreases, the input voltage might become too low to make the lamps glow faintly during normal operation; however, the lamps would still light if an open circuit occurs and short circuits could be tested by temporarily increasing the voltage.

Because control of room temperature is manual, changes in room temperature above the set point will be indicated by a signal light located on the control panel. A low limit control or indicator is not required for the frozen stores room as no danger of food spoilage is involved in lowering room air temperature below 0 F. The chill stores room operating at 33 F, however, must be protected against a decrease in temperature that might freeze the food. Thermally actuated contacts used in conjunction with relays or silicon controlled rectifiers will be used to remove one of the series circuits from the line to prevent freezing of the food. This circuit would be powered again upon a rise in temperature to a predetermined level.

CONCLUSION

THE INFORMATION that has been obtained from this study has demonstrated that a thermoelectric refrigeration system is feasible for operation aboard present-day submarines. The performance of the system, although not equal to that of a conventional compressor system, is of a sufficient level, using thermoelectric materials available today, to keep power demands to a reasonable level.

A method of design which is felt to be quite practical in approach from the standpoint of optimization of system performance within limitations of present manufacturing knowledge has been outlined. This system involved "derating" of the theoretically optimized performance of the thermoelectric system by factors such as practical leg configuration, variation in the magnitude of the thermoelectric material parameters, junction resistance, and current ripple.

The expected performance of the complete refrigeration system was presented under normal operation at design conditions and under emergency conditions such as component failure in the system and change of heat sink temperature.

The design of the power supply, control, and module failure warning system was shown to be dependent on system reliability which determines not only gross power requirements but also wiring networks for each system.

REFERENCES

1. E. Altenkirch. *Zeitschrift fuer Physik*, Berlin, Germany, vol. 12, 1911, p. 920.

2. Semiconductor Thermoelectric Cooling and Thermoelements (book), A. F. Ioffe. Infosearch Ltd., London, England, 1957.

Missile Tracking

Highly accurate tracking of missiles, space satellites, and aircraft will be possible with the new Precision Instrument Mount (PIM) designed and built by American Machine & Foundry Company for the U. S. Army Signal Corps. Incorporating the latest electrical, servomechanical, and optical principles, the AMF tracking device can be used for direct reading by an operator or recording data on film. PIM provides exceptional quantity and quality of information and is small enough to be dismantled and relocated easily.

Measurement of Materials for Thermoelectric Generators

C. S. DUNCAN
MEMBER AIEE

G. W. WILSON

This article presents the various aspects of thermoelectric generator material measurement. Engineers need to be informed not only of the "how" of measurements but also of just what the various measurements can reveal and which ones are needed for a specific purpose.

THE efficiency of a thermoelectric generator used for the conversion of thermal into electric power is, in general, a function of two sets of parameters:

1. The temperatures between which the thermocouples in the generator are operated. These are usually taken to be the temperature of the heat source and of the heat sink.

2. Three parameters of the materials used in the thermocouple comprising the Seebeck coefficient, the electrical resistivity, and the thermal conductivity. These three properties are generally combined into a figure of merit z[1] where

$$z = \frac{S^2}{\kappa\rho}$$

for a single material of one type and

$$z = \frac{(|S_p| + |S_n|)^2}{(\sqrt{\kappa_p \rho_p} + \sqrt{\kappa_n \rho_n})^2}$$

for two materials having p- and n-type electrical conductivity such as would form a complete thermocouple. Here

S = Seebeck coefficient in volts per degree C
κ = thermal conductivity in watts per centimeter per degree C
ρ = electrical resistivity in ohm-centimeters

The expression for the optimized efficiency of a thermocouple as a generator is

$$\eta_{opt} = \frac{T_h - T_c}{T_h} \times \frac{M - 1}{M + \left(\frac{T_c}{T_h}\right)}$$

where

M = ratio of load resistance to internal resistance of thermocouple

$$= \sqrt{1 + \frac{1}{2} z (T_h + T_c)}$$

This efficiency obviously reaches a maximum between any two temperatures T_h and T_c, which are in degrees K, when M is as large as possible; i.e., z is as high as possible.

Generally, the material parameters S, ρ, and κ and, therefore, the figure of merit into which they can be combined, are temperature dependent. Hence, in order to cover a wide temperature range in a generator and to obtain a high Carnot efficiency, it is necessary to use a number of different thermoelectric materials which achieve maxima in their figures of merit at different temperatures. There are two principal methods of using a number of different thermoelectric materials in a generator, i.e., by cascading a number of stages in thermal series, or by connecting several materials electrically and thermally in series in the legs of each thermocouple. The former case gives what is generally known as a cascaded or staged generator,[2] the latter a segmented generator. In both instances, however, the resulting performance depends upon the same two sets of variables as in the simple case, and increasing the figures of merit of the materials generally improves the efficiency obtained.

In order to use a number of materials of both p and n type in a thermoelectric generator to their maximum advantage, it is necessary to know how their figures of merit depend upon temperature since any one will in general possess a better z in one temperature range than another.

Thus, to design a thermoelectric generator one needs the following data: (1) the values of S, ρ, and κ and their variation with temperature, and, hence, (2) the value and variation of z with temperature.

A generator intended to produce appreciable amounts of electric power requires a large number of thermocouples using considerable quantities of material, and it is therefore generally necessary to measure some if not all of the thermoelectric parameters of the materials used as a form of quality control.

The properties of S, ρ, and κ are not independent of each other and, therefore, as will be shown later in this

A special article recommended for publication by the AIEE Solid State Devices Committee.

C. S. Duncan and G. W. Wilson are with the Research Laboratories, Westinghouse Electric Corporation, Pittsburgh, Pa.

The authors wish to thank their colleagues J. E. Bauerle, R. C. Miller, and R. W. Ure for their help in preparing this article. They also wish to acknowledge the support of the Bureau of Ships, U. S. Navy.

article, it is not always necessary to measure all three parameters to determine the thermoelectric characteristics of a material.

EFFECTIVE PARAMETERS

FOR EACH THERMOELECTRIC MATERIAL, the parameters S, ρ, and κ are customarily measured at a variety of points of temperature. These measurements subsequently are plotted to provide a graphical representation of the temperature dependence of each parameter. From such curves, one can obtain for each parameter an effective value to apply over any temperature range in which it would be desirable to employ a particular material in a generator. These measurements are obviously time consuming and often cannot be justified in situations requiring the evaluation of a large number of specimens.

Effective parameter values also can be obtained by means of direct measurements[3,4] which are made while the specimen is held at the ΔT over which it is intended to operate that particular material. By this method, effective values can be obtained in a small fraction of the time which would be required by the previously described method. The direct method also has the advantage of placing the specimen under a matched electric load which in turn allows a direct measurement of efficiency.

Effective parameters, as measured directly with a large ΔT on a material pellet of length l and area A, are

$$\kappa = \frac{q_o}{T}\left(\frac{l}{A}\right)$$

where

q_o = the open circuit heat flow rate

$$\bar{\rho} = \bar{r}\left(\frac{A}{l}\right)$$

and

$$\bar{S} = \frac{E_o}{T}$$

where

E_o = the open circuit voltage across the pellet

Table I. Room Temperature Values for Some Thermoelectric Materials

Material	Room Temperature in (30°) Properties				High Temperature Figure of Merit	
	S, volts °C^{-1}	κ (x 10^{-2}) cm^{-1},°C^{-1}	ρ (x 10^{-4}) ohm-cm	z (x 10^{-3}) °C^{-1}	ΔT, °C	z (x 10^{-3}) °C^{-1}
$Bi_2Te_{2.4}Se_{0.6}$	−132	2.1	5	1.65	170-30	1.58
	−200	1.5	11	2.4	170-30	2.2
PbTe (cast)	−135	3	4.7	1.3	300-170	1.75
PbTe (pressed and sintered)	−108	2.275	5	0.8	530-300	1.25
	−130	2.5	4	1.7	530-300	1.0
$Bi_2Sb_2Te_3$	+136	2.0	4.8	1.96	170-30	1.85
	+197	1.5	9	1.87	170-30	<1
ZnSb	+168	2.23	13	0.66	330-170	1.2
GeTe	+ 28	9.4	1.1	0.06	630-530	0.92

Also

$$\bar{Z} = \frac{\bar{S}^2}{\bar{\rho}\,\kappa}$$

Thermocouple efficiency is expressed as

$$\epsilon_T = \frac{\sqrt{1+\bar{Z}\,T_{av}}-1}{\sqrt{1+\bar{Z}\,T_{av}}+\frac{T_c}{T_h}}$$

where

$$T_{av} = \frac{T_c + T_h}{2}$$

Over-all device efficiency is expressed as

$$\eta_o = \epsilon_T \cdot \frac{\Delta T}{T_h}$$

where

$\frac{\Delta T}{T_h}$ = Carnot efficiency

Over-all efficiency, as obtainable by direct measurement, is also expressed as

$$\eta_o = \frac{P_L}{q_L}$$

where

P_L = power in watts dissipated in the optimum load attached to pellet

q_L = heat rate into pellet under load

ROOM TEMPERATURE MEASUREMENTS

WHEN ONCE careful laboratory measurements have established the optimum composition with respect to doping of each of a number of useful thermoelectric materials and have enabled point-by-point determinations to be made of S, ρ, and κ over a range of temperatures, it is possible to obtain a great deal of information from a few measurements for subsequent batches of the same material. Thus, Table I lists the room temperature values of S, ρ, κ, and z for a number of materials over a ΔT.

Of all property determinations, measurements of the thermal conductivity are the most difficult and time consuming to carry out; however, as will be shown, it is possible in the majority of cases to eliminate this from any measurement schedule when once reliable point-by-point data are available.

Thermal conductivity can be divided into two parts: a component κ_e due to the charge carriers and κ_l due to vibrations in the atomic lattice.

$$\kappa = \kappa_e + \kappa_l$$

The former is related to the electrical resistivity by the Wiedemann-Franz-Lorenz relationship

$$\kappa_e\,\rho = 2\left(\frac{k}{e}\right)^2 T$$

where

k = Boltzmann constant
e = electronic charge
T = absolute temperature

The lattice component κ_1 is for most practical purposes independent of electrical resistivity. Thus, from the initial point-by-point data, a graph of κ_1 vs. T may be obtained. This generally has the form shown in Fig. 1. For most materials

$$\kappa_1 \propto \frac{1}{T}$$

Subsequently, in order to determine the thermal conductivity of any material of the same composition, whatever additions are made to change S and ρ, it is necessary only to measure the latter at the temperature of interest. κ_1 is then read graphically and the total thermal conductivity is obtained by adding to it the value

$$2\left(\frac{k}{e}\right)^2 \frac{T}{\rho}$$

MATERIAL PARAMETERS AS A FUNCTION OF TEMPERATURE

As has been mentioned previously, in order to design a thermoelectric generator using several materials, it is necessary to know the variation of the figure of merit z with temperature. In order to do this, the temperature variation of Seebeck coefficient, thermal conductivity, and electrical resistivity are required. Although a method of deriving z directly in one apparatus has been suggested,[5] the separate measurement of S, ρ, and κ is necessary for the completion of the design calculations. The effective parameters mentioned in a previous section may be obtained by graphical integration using the equations

$$\bar{S} = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} S\,(T)\,dT$$

$$\bar{\kappa} = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} \kappa\,(T)\,dT$$

$$\bar{\rho} = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} \rho\,(T)\,dT$$

The first experimental procedure to be outlined

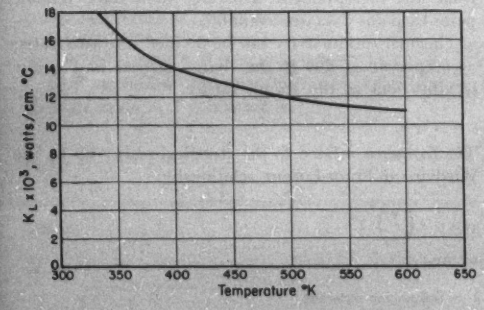
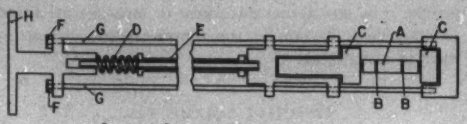
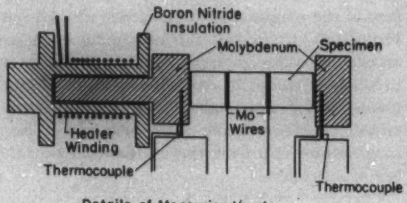


Fig. 1. The variation of K_L with temperature for cast PbTe.



General Sketch of Whole Apparatus.



Details of Measuring Head

Fig. 2. Apparatus for measuring S and ρ as a function of temperature.

enables measurements of S and ρ to be made at temperatures up to 1,000–1,100 C.

The measurement of thermal conductivity is very much more difficult as a number of systematic errors occur which can readily give rise to large errors in the measured value of the thermal conductivity. In general, the errors involved in the measurements of thermal conductivity of low-conductivity materials, such as are used in thermoelectric applications, are appreciably greater than those arising in the determination of S and ρ.

THE MEASUREMENT OF S AND ρ

The apparatus used is shown in Fig. 2. The specimen labeled A should have a length-to-diameter ratio of 3 or more to ensure that the current distribution in the specimen is as uniform as possible. The specimen has two grooves labeled B and B cut around its circumference a known distance apart. It is positioned between two molybdenum cylinders C, thermal and electrical contact to the specimen being made by pressure applied to one of these blocks by means of a spring D, transmitted through the steel sleeve E. The spring and rod are insulated from the molybdenum cylinder by the use of boron nitride.

This boron nitride has wound on it a heating coil as shown in Fig. 2. In each molybdenum block adjacent to the faces which bear against the specimen, small holes are drilled parallel to these end faces. Into these thermocouples are inserted, the bead of each thermocouple making good thermal and electrical contact to the block in which it is imbedded.

In use, two thin molybdenum wires are wound once around the specimen in each groove and twisted as shown to ensure good electrical contact with it. The two ends of the specimen are polished or ground flat to make good contact to the ground surfaces of the molybdenum cylinders. Compression is applied to the

specimen by tightening the screws F on the three rods G. All electrical leads are brought out through seals in the flange H, which also enables the whole assembly to be mounted inside a furnace. Stainless-steel-jacketed thermocouples are employed, and in measuring specimen resistivity they are used to supply direct current to the specimen.

In order to make a measurement, the furnace tube is first evacuated and then backfilled with a nonoxidizing gas having a high thermal conductivity; e.g., helium or hydrogen. The temperature of the assembly is then raised to the desired level, its position in the furnace being adjusted so that the molybdenum block which sits inside the heater coil is at a slightly lower temperature than the other end of the specimen. Power is supplied to the heater coil until the temperatures of the two molybdenum cylinders are equal. A known direct current is then passed through the thermocouple sheaths, and the potential difference between the two molybdenum wires wrapped around the specimen is measured using a potentiometer. Two readings are taken with the current flowing in opposite directions and the mean is used to compute the resistivity.

To measure the Seebeck coefficient, the power supplied to the heating coil is increased, thereby inducing a small temperature gradient in the specimen. The temperatures of the two molybdenum cylinders are then measured, followed by a determination of the potential difference between these cylinders using one lead of each thermocouple. If the potential measured in this way is ΔV and the temperature interval is ΔT, the Seebeck coefficient of the specimen against the material from which the two thermocouple wires used in this measurement are made is $\Delta V/\Delta T$. This must then be corrected to convert the value of S to that conventionally used where S is quoted for a material against either lead or platinum.

Errors can arise in these measurements for several reasons. Thus, contact resistance between the molybdenum wires and the specimen can cause errors in the resistivity. Also, care must be taken to ensure that thermal equilibrium is reached between the pellet and its surroundings after any change in the power input to the furnace or separate heater winding. Thermal contact resistances can also arise but these are minimized by the use of helium or other gases having a high thermal conductivity. The thermocouple leads must be made small in area to minimize thermal losses. Several references are available which give full descriptions of the sources of possible error but, in general, it is possible to obtain values of S and ρ by the method aforementioned to within $\pm 10\%$.

THE MEASUREMENT OF THERMAL CONDUCTIVITY

THE MEASUREMENT TECHNIQUE to be described is not an absolute method but is one based upon a comparison between the temperature drop occurring in the specimen of known geometry but unknown thermal conductivity and that occurring in a sample where both of these quantities is known under conditions where the heat leaving one specimen is equal to the heat entering the other. It is a modification due to Bauerle of a method employed by Francl and Kingery.[6] It has been employed to measure thermal conductivities at temperatures up to 900 C.

The apparatus used is shown in Fig. 3. The thermoelectric specimen is placed between two standard pellets of known thermal conductivity having identical diameters positioned between two plugs whose temperatures are adjusted by heaters A and G. The standard pellets were made from high purity dense alumina, whose thermal conductivities had been accurately measured by comparison with Armco iron. As shown in Fig. 3, temperatures are measured in each of the three pellets by means of fine wire thermocouples 1, 3, 5, 6, 8, 9. The holes in the pellets necessary to accommodate these are made as small as possible in order to try to maintain an even heat flow. In order to reduce radial heat flow to the lowest possible value, a fused alumina guard ring wound with five individually powered heaters surrounds the inner assembly. By adjustment of these heaters, the temperature and temperature gradient in the guard ring as measured by thermocouples 2, 4, 7, and 10 are made equal to those appearing in the standards and specimen. A supply of helium is passed slowly through the zirconia granules.

The thermal conductivity of the unknown sample is given by the two equations

$$\kappa_\beta = \kappa_\alpha \frac{L_\beta \, \Delta T_\alpha}{L_\alpha \, \Delta T_\beta}$$

and

$$\kappa_\beta = \kappa_\gamma \frac{L_\beta \, \Delta T_\gamma}{L_\gamma \, \Delta T_\beta}$$

where

α and γ = the two standards
β = thermoelectric specimen
L_α, L_β, and L_γ = distances separating thermocouples 1 and 3, 5 and 6, 8 and 9, and the ΔT's are measured over these lengths.

By averaging the two values obtained, some degree of compensation can be made for longitudinal asymetries in heat flow.

THE MEASUREMENT AND USE OF EFFECTIVE PARAMETERS

EFFECTIVE PARAMETERS can be obtained by making measurements of materials while they are operating exactly as in an actual generator. After the hot-junction and cold-junction temperatures for a particular material have been chosen, it is necessary to subject the test specimen to this exact temperature interval. While a test specimen is held at this interval, its resistance, thermal conduction, and open circuit voltage are measured, and the resistivity, thermal conductivity, and Seebeck coefficients can thus be obtained, and are likewise effective for this ΔT. By electrically loading the test specimen with an optimum load resistance, it is

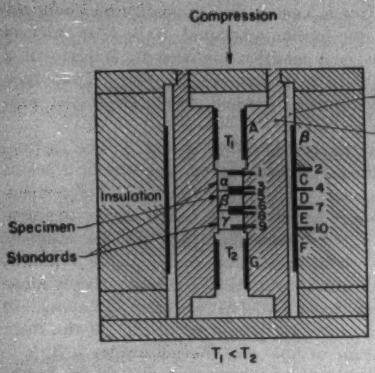


Fig. 3. Apparatus for measuring thermal conductivity and its variation with temperature.

also possible to obtain a direct measure of its over-all thermal efficiency. Apparatus for measuring effective parameters has been built to operate in air for hot junction measurements up to 450 C and, in an inert atmosphere for hot junction measurements, up to 700 C.

Two types of apparatus have been used to make measurements of effective thermal conductivity. One apparatus measures electric watts into the heat-source heater; in this apparatus a thermal guard is maintained around the heat source in such a manner that the only heat loss from the heat source is that which flows into the thermoelectric material pellet under test. The other type of apparatus utilizes a calorimetric measurement of heat flowing out of the material pellet under test. The latter of these is of the simpler construction and is shown schematically in Fig. 4. The material pellet under test is shown situated between a heat source *a*, and a water cooled heat sink *b*. In normal use, the heat sink serves a dual purpose: (1) it establishes a heat sink temperature of about 30 C, and (2) it provides a calorimetric measure of the heat entering the sink. The calorimetric measurement is carried out by measuring the water temperature rise between the inlet and outlet of the cooling coil and by measuring the rate of water flow at the same time. Since some heat will reach the calorimeter without having gone through the material pellet under test, it will be necessary to calibrate the system by measuring the heat reaching the calorimeter when an insulating pellet is mounted in the apparatus. It is further necessary that such an insulating pellet either be of a known thermal conduction or be of negligible thermal conduction as related to the thermal conduction of the thermoelectric pellet to be measured. In normal operation, the heat sink and calorimeter are each at approximately 30 C.

If it is desired to measure a material at an elevated cold junction temperature, two alternatives are available: (1) determine $\bar{\kappa}$ by measuring $\bar{\rho}$ and $\bar{S}$ in the aforementioned apparatus and use the previously described method for calculation of $\bar{\kappa}$, or (2) measure $\bar{\kappa}$ by apparatus of the alternate design described in the previous paragraph. These alternatives are suggested because of thermal measurement errors which are introduced when the heat sink is operated at an elevated temperature and also because such errors are difficult to measure accurately. The cold junction temperature can be determined by the value of the thermal resistor *c*, which is located between the heat sink *b* and the heat exchanger portion of the calorimeter. The thermal resistor is usually constructed of stainless steel and its value is adjusted by variation of its diameter.

Special consideration must be given to the thermal and electric contacts of the thermoelectric material specimen being tested. For accurate parameter measurements, these contacts must be either of negligible thermal and electric resistance or of a known and closely measurable resistance. In this apparatus, contact for test purposes is usually made by use of a gallium-indium eutectic alloy which is liquid at room temperature and which also possesses exceptional wetting properties. When measuring compatible materials, such as ZnSb, it is satisfactory to apply the alloy directly onto the thermoelectric material if so desired. When measuring thermoelectric materials which will alloy with GaIn, it is necessary first to apply a suitable permanent contact. Special provision also must be made to prevent the faces of the heat source and heat sink from alloying with GaIn at elevated temperatures. The source and sink, which are constructed of copper, are faced with molybdenum which is joined by a special furnace braz-

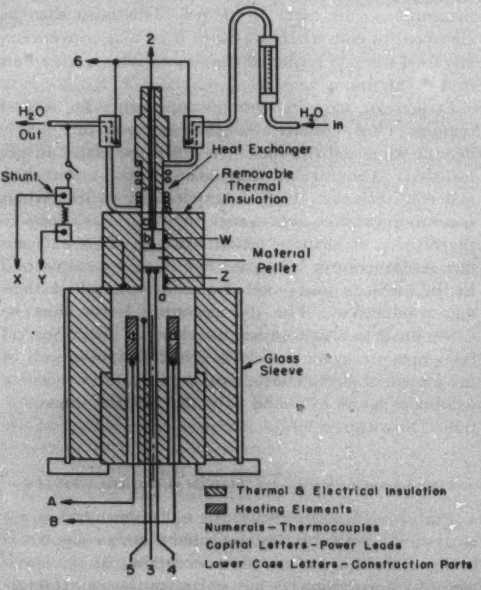


Fig. 4. Apparatus for measurement of effective parameters.

ing operation. Molybdenum is inert to GaIn to temperatures above 700 C. When GaIn is properly applied to form a contact, its electrical resistance is negligible as related to typical thermoelectric specimens. The thermal drop through a 0.5-inch-diameter area is about 0.3 C per thermal watt.

As in all thermoelectric measurement devices, care must be exercised to insure that unintended thermal voltages do not enter into the measurements. In this apparatus all parts of the measuring circuit, excluding the test specimen, meet at least one of the following requirements: (1) each ΔT of any consequence must be confined to circuit materials of negligible or known Seebeck coefficient relative to that of the test specimen, and (2) each material of appreciable Seebeck coefficient must be subjected to, at most, a negligible ΔT. Another point of caution that must be observed is the relatively high current and low voltage of a single thermoelectric pellet operating into a matched load. Since a pellet under these conditions might typically deliver 20 amperes at 40 millivolts, it is readily apparent that even as little as 0.1 milliohm, in an inappropriate circuit location such as a pellet contact, can cause an appreciable error in measurements. The typical pellet resistance of 2 milliohms also requires the use of careful design in order that a matching load circuit resistance be achieved.

The following measurements were made on a test specimen of ZnSb

$$\eta_o = \frac{P_L}{q_L} = \frac{35.8 \times 10^{-3} \times 20.5}{9.77 + 0.734} = \frac{0.734}{10.5} = 6.99\% \quad (1)$$

$$\epsilon_{Carnot} = \frac{\Delta T}{T_h} = \frac{433}{725} = 0.597 \text{ or } 59.7\% \quad (2)$$

$$\epsilon_T = \frac{\eta_o}{\epsilon_{Carnot}} = \frac{6.99}{0.597} = 11.7\% \quad (3)$$

$$\bar{\kappa} = \left(\frac{l}{A}\right) \times \frac{q_o}{T} = 0.816 \times \frac{8.48}{433} = 0.016 \text{ watts per centimeter per degree C} \quad (4)$$

$$\bar{\rho} = \left(\frac{A}{l}\right) \times \frac{E_o - E_L}{I_L} = 1.255 \times \frac{47.2 \times 10^{-3}}{20.5} = 0.0028 \text{ ohm-centimeter} \quad (5)$$

$$\bar{S} = \frac{E_o}{\Delta T} = \frac{83.0 \times 10^3}{433} = 192 \ \mu \text{ v per degree C} \quad (6)$$

$$\bar{Z} = \frac{\bar{S}^2}{\bar{\rho}\,\bar{\kappa}} = \frac{(192 \times 10^{-6})^2}{0.016 \times 0.0028} = 0.825 \times 10^{-3} \text{ per degree C} \quad (7)$$

$$\epsilon_T = \frac{\sqrt{1 + \bar{Z}\,T_{av}} - 1}{\sqrt{1 + \bar{Z}\,T_{av}} + \left(\frac{T_c}{T_h}\right)} \quad (8)$$

$$\epsilon_T = \frac{\sqrt{1 + 0.823 \times 10^{-3} \times 508} - 1}{\sqrt{1 + 0.823 \times 10^{-3} \times 508} + \left(\frac{292}{725}\right)} \quad (9)$$

$$\epsilon_T = 11.96\% \quad (10)$$

$$\eta_o = \epsilon_T \cdot \epsilon_{Carnot} = 11.96 \times 0.97 = 7.14\% \quad (11)$$

Equation 1 illustrates how the over-all thermal efficiency of a material has been measured directly as the ratio of electric power output divided by the thermal power input. The electric power output, $P_L = 0.734$ watt, is the product of the load voltage, 35.8 millivolts, and the load current, 20.5 amperes. In this case, the load current is only at approximately its optimum value, but the error thus introduced can be neglected since the absolute value is not critical with materials of this figure of merit. The thermal energy rate delivered to the pellet, $q_L = 10.5$ watts, is the sum of the thermal power flowing out of the pellet, 9.77 watts as measured by the calorimeter, and the thermal power converted to electric power, 0.734 watt. The over-all thermal efficiency $\eta_o = 6.99\%$ is the product of the Carnot efficiency, ϵ_{Carnot}, and the thermoelectric effiiciency ϵ_T. Since the absolute temperature of the hot and cold junctions are known, the Carnot efficiency is easily computed as in equation 2 and the thermoelectric efficiency is obtained in equation 3.

The effective thermal conductivity $\bar{\kappa}$ is obtained in equation 5 as a product of the geometry factor, l/A, and the ratio of the heat conducted, q_o, to the temperature difference, ΔT, required to produce that heat flow. It should be noted that q_o is the heat conducted while no electric current is passing through the pellet and is not equal to the q_L of equation 1. In equation 5, the effective resistivity $\bar{\rho}$ is obtained by dividing the voltage drop resulting from loading, by the load current which is produced as a consequence of that loading. The effective Seebeck coefficient, $\bar{S}$, is the quotient obtained from division of the total voltage generated, E_o, by the ΔT required to produce that voltage.

From the effective values of $\bar{S}$, $\bar{\rho}$ and $\bar{\kappa}$, the thermoelectric efficiency can be computed as shown in equations 7 through 10. Over-all efficiency η_o is computed in equation 11 and is seen to compare closely with the directly measured efficiency of equation. 1.

Because of its speed, the apparatus for measurement of effective parameters is especially useful for quality control purposes. Thermal equilibrium suitable for measurement of $\bar{S}$, $\bar{\rho}$, and $\bar{\kappa}$ can be achieved in approximately 5 to 10 minutes when a water-temperature cold junction is used. If a direct measure of efficiency is also desired, an additional 5 to 10 minutes will be required for thermal stabilization with the material under electric load. If it is necessary to test a material with an elevated cold-junction temperature, approximately 20 minutes will be required to achieve thermal equilibrium such that $\bar{S}$ and $\bar{\rho}$ can be measured and $\bar{\kappa}$ can be calculated. Many materials, which might desirably be used with an elevated cold junction can be tested with a water-temperature cold junction and still provide quality control data applicable to the intended temperature. This alternate procedure, where applicable, results in a substantial saving of time.

Composite material legs, legs which comprise two or more thermoelectric materials connected in series both thermally and electrically, can be measured as would a single material. It should be made clear that whether single or composite material legs are measured, the specimen corresponds to only one leg of a thermoelectric

couple. To obtain the complete figure of merit for a couple, the second leg must also be measured. The figure of merit for a couple, given at the beginning of this article, can then be used to combine the parameters for each leg. If the efficiency of a couple is to be obtained by direct measurement, it is necessary to measure each leg separately and obtain the couple efficiency by using the total electric power output and the total thermal power input.

MEASUREMENT OF PARAMETERS AT ROOM TEMPERATURE

IT WAS POINTED OUT earlier that a room temperature measurement of resistivity or Seebeck coefficient can serve, in many cases, as a quality control measurement sufficient to characterize material over a much higher range of temperature. Although a wide variety of apparatus has been made for this purpose, it is not appropriate here to describe all of them.

We prefer a potential profile method for purposes of room temperature resistivity measurement. The profile method is especially valuable because it provides not only a measurement of resistivity but also offers the following additional advantages: (1) a profile which indicates the uniformity of the resistivity, (2) a detection means for locating fractures which are in a direction normal to the flow of current, and (3) a means of contact resistance evaluation. The main objection to the potential profile method is its relatively slow rate of operation. In order to obtain faster results a mechanized version of the profile method is suggested (Fig. 5). The position indicated as *Y2* is a sliding inclined probe applied with a spring force. End contacts for short pellets are especially important and most of the contact suggestions mentioned in the previous section should be followed with this apparatus. When long bars are measured, relatively poor contacts can be safely used, provided the results near the ends are neglected. A traverse rate of 2 inches per minute has been found to work satisfactorily with this apparatus.

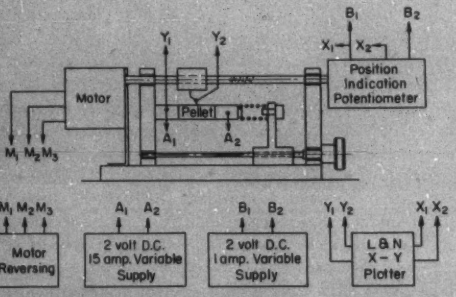


Fig. 5. Apparatus for automatic measurement of room-temperature potential profile.

Room temperature Seebeck coefficients can easily be found with an apparatus such as that sketched in Fig. 6. In this device the pellet is held under spring compression between a copper-block heat source which remains at room temperature and a water-cooled heat sink which will remain a few degrees below room temperature. The difference of temperature between the heat source and the heat sink is measured at points *B* as the output of two opposed-polarity measuring thermocouples. The Seebeck voltage is measured, preferably by a potentiometer, at points *A*.

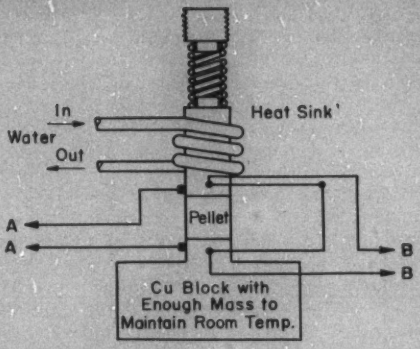


Fig. 6. Apparatus for measurement of room-temperature Seebeck coefficient.

REFERENCE

1. Semiconductor Thermoelements, and Thermoelectric Cooling (book). A. F. Ioffe. Infosearch, London, England, 1957.

2. Multiple Stage Thermoelectric Generation of Power, T. C. Harman. *Journal of Applied Psysics*, New York, N. Y., vol. 29, no. 10, Oct. 1958.

3. Measurement of Thermoelectric Materials under Simulated Generator Conditions—I, S. J. Angello, C. S. Duncan. AIEE Conference Paper 59-329, Feb. 3, 1959.

4. Measurement of Thermoelectric Materials under Simulated Generator Conditions—II, S. J. Angello, C. S. Duncan. AIEE Conference Paper 59-961, June 25, 1959.

5. Special Techniques for Measurement of Thermoelectric Properties (letter to the editor), T. C. Harman. *Journal of Applied Physics*, New York, N. Y., vol. 29, no. 9, Sept. 1958, p. 1373.

6. Thermal Conductivity: IV, Apparatus for Determining Thermal Conductivity by a Comparative Method, J. Francl, W. D. Kingery. *Journal*, American Ceramic Society, Columbus, Ohio, vol. 37, Feb. 1954 (pt. II), pp. 80-84.

Underwater Laboratory

Completion of a new laboratory facility to develop underwater fuel element handling techniques and devices has been announced by Allis-Chalmers Manufacturing Co. Located at the firm's Greendale (Wis.) Laboratories, the facility consists of an 11-foot diameter by 40-foot high tank containing 30,000 gallons of reactor grade demineralized water and a full scale mock-up of one eighth of the reactor core for the Pathfinder Atomic Power Plant. When immersed in the tank, the mock-up core will be at the same depth as the core in the power reactor vessel.

High-Temperature Effects on Magnetic Core Materials

MICHAEL PASNAK RICHARD LUNDSTEN

A STUDY of the effects of high temperature on the properties of magnetic core materials was made to facilitate the development of military components for operation under extreme environmental conditions. The following materials were studied: Transformer *A*; Audio Transformer *A*, *L* and *Z* Silectron; Orthonol; *AEM 4750; 4-79 Mo* Permalloy; *11.7* Alfenol; *15.5* Alfenol; *3 Mo* Thermenol; Supermendur; and *7-70* Perminvar.

Each of the materials was tested at temperatures up to 500 C in 100 C steps or until the Curie point of the material was exceeded, if the Curie point was below 500 C. In order to insure temperature stability, the materials were allowed to remain at each temperature for a period of 1 hour before testing. After being tested at 500 C or at the Curie temperature, whichever was lower, the materials were allowed to furnace cool back to room temperature. Following the room temperature retest, the material temperature was raised directly to 500 C, or to its Curie temperature, and retested. This cyclic procedure was repeated three times. The cores were then furnace cooled from 500 C or the Curie temperature at a faster cooling rate by removing the furnace cover.

Additional specimens of the materials whose Curie points were above 500 C, were tested at room temperature and taken directly to 500 C and tested. The temperature was then raised from 500 C, in steps of 100 C, until the Curie temperature was exceeded for each material. Tests were made at each temperature level. Lastly, the materials were allowed to furnace cool to room temperature and retested.

Standard d-c test methods were used to obtain the static magnetic properties. The 60-cps dynamic loops, which were recorded by a new instrument called the Ferrotracer, were obtained with the test core driven by a sine wave "current source."

Results and Conclusions are the following:

1. All materials, with the exception of *11.7* Alfenol and Supermendur, indicated a continuous decrease in residual and maximum flux densities, coercive force, and rectangularity at 30 oersteds.

2. The maximum permeability increased with increasing temperature until the Curie temperature was approached, then it started to decrease. The initial permeability also increased with increasing temperature but unlike the maximum permeability, it generally started to decrease at a lower temperature.

3. All materials, with the exception of Supermendur and *11.7* Alfenol, indicated a continuous decrease in total core losses (measured at a constant field) with increasing temperature. Supermendur showed a continuous increase in total core losses from 24 C to 300 C before any decrease occurred. With increasing temperatures, *11.7* Alfenol first showed a continuous decrease in total core losses, but at 500 C its total core losses increased.

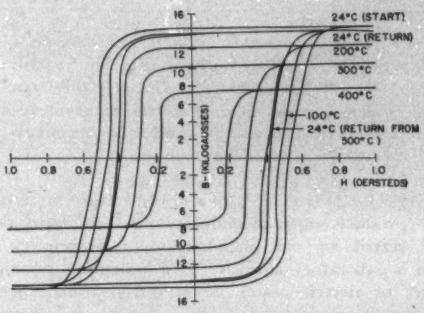


Fig. 1. 60-cycle dynamic loops of Orthonol (tape) in the temperature range of 24 C to 400 C.

4. In the silicon-iron family of alloys, the detrimental effect of high temperature on the magnetic properties is attributed to oxidation in both the grain oriented and unoriented materials, and to disorientation in grain oriented materials.

5. Because alloys of the aluminum-iron family depend upon the order-disorder conditions for optimum magnetic properties, the cores showed critical dependence upon the cooling rate and operating temperature.

6. Since the unoriented nickel-iron alloys are relatively insensitive to cooling rates, they essentially retained their initial properties after temperature cycling.

7. When *7-70* Perminvar was cooled from 700 C, inferior magnetic properties resulted, as would be expected, since its magnetic properties are dependent upon magnetic annealing and cooling rate.

8. The detrimental effects of elevated temperatures upon the magnetic properties of Supermendur appeared to be due to order-disorder phenomena and phase changes taking place within the material. Cooling rate is of paramount importance in that it determines the degree of ordering. Since the optimum properties of Supermendur below 300 C were also due to domain orientation, cooling from 500 C without a magnetic field produced inferior magnetic properties.

Digest of paper 59-1117, "Effects of Ultra High Temperature on Magnetic Properties of Core Materials," recommended by the AIEE Basic Sciences Committee and approved by the AIEE Fall General Meeting, Chicago, Ill., Oct. 11-16, 1959. Published in AIEE *Communication and Electronics*, Jan. 1960, pp. 1033-39.

Michael Pasnak and Richard Lundsten are with the U. S. Naval Ordnance Laboratory, Silver Spring, Md.

THERMOELECTRICITY

Thermoelectric Refrigeration

W. L. WRIGHT

Practical thermoelectric cooling has become a reality with the development of thermoelectric semiconductor materials. To illustrate this type of cooling, several devices which represent applications in the electronics industry and medicine are described.

THERMOELECTRIC semiconductor materials, products of semiconductor research, have converted an old phenomenon, thermoelectricity, from a laboratory curiosity to a potential, practical source of electric power, or of refrigeration. Recent progress in materials has made it possible to construct thermoelectric generators with capacities up to 5 kw as well as thermoelectric refrigerators with cooling capacities of up to several hundred Btu per hour.

Establishment of practical thermoelectric cooling fills a gap, in regard to capacity, in refrigeration systems. Vapor compression systems have a lower practical capacity limit of approximately 100 Btu per hour. Other refrigeration systems, such as vapor adsorption, suffer disadvantages which limit their use in applications requiring less than 100 Btu per hour.

The number of applications within this low cooling capacity range are increasing rapidly and in importance. This is particularly true in the electronics industry. Medicine and its related sciences represent another important field of application for thermoelectric cooling. The oil and food industries are additional potential fields of application.

Small size, simplicity, and reliability of thermoelectric coolers further enhance their potential use. These advantages as well as the growing field of application for thermoelectric refrigeration can best be illustrated by describing several thermoelectric refrigeration devices. The majority of the applications described herein are primarily for use in electronic equipment or by scientific laboratory, hospital, or related environment. Brief mention will be made of two other interesting thermoelectric cooling projects: the development of a 1-ton shipboard air conditioner and an air-conditioned personnel garment.

INFRARED-DETECTOR COOLER

SEMICONDUCTOR infrared detectors are limited in sensitivity by the presence of background noise within the cell. As is well known, lowering of the temperature of an infrared detector markedly lowers the background noise and, thus, increases sensitivity of the device. Cooling of detector cells has been accomplished by use of dry ice or other cooling agents which, in time, lose their cooling ability. A thermoelectric cooler offers the advantage of direct application to the surface requiring cooling, in addition to an apparently infinite life.

Fig. 1. Exploded view of infrared-detector cooler.

Consider for a few moments the design of a device which can be used for cooling an infrared detector. First, a surface must be provided which will conduct heat as directly as possible from the surface requiring cooling to the cold junctions of the thermoelectric couples. This is shown as item 1 in Fig. 1. This item must be a good thermal conductor and in some manner provide electrical isolation from the thermoelectric couples. This necessary requirement will become clear later. In this case, aluminum is used for the heat conductor. Positive electrical insulation can be obtained by hard-anodizing the surfaces of the piece. The necessary cooling capacity is furnished by three thermoelectric couples which are shown as item 2 in Fig. 1. The couples are arranged as shown with their cold junctions in one plane and connected electrically in series. In this application, the thermoelectric material used is in cylindrical form, the six pellets being connected in series by means of the copper straps shown. The assemoly of thermoelectric material and copper straps as shown were joined together in one operation using jig soldering techniques.

The electric power consumed in pumping heat appears as heat at the hot junctions of the thermocouples. This heat and the heat pumped must be dissipated

A special article recommended by the AIEE Solid State Devices Committee.

W. L. Wright is with the Westinghouse Electric Corporation, Pittsburgh, Pa.

from the hot junctions by some form of heat exchanger. In this application, a free-convection heat exchanger, shown as item 4, is used to dissipate heat from the hot junctions to the ambient atmosphere. As shown, the heat exchanger is finned to provide a large surface in contact with the atmosphere. Made of aluminum, it is anodized black for better heat transfer and to provide electrical insulation between the heat exchangers and hot junctions. The thermocouples are held in compression between the heat exchanger and cold plate (item 1) by two nylon screws. This forces all of the thermal surfaces into the necessary intimate contact. Heat leakage into the cold junctions is reduced by the use of a Micarta (registered trade mark) resin box, item 3, which is filled with insulation that completely surrounds the thermoelectric couples. The box is fastened to the hot-junction heat exchanger to provide a completely sealed-in unit with only the cold surface protruding. Electrical connection to the thermocouples is made through the insulating standoffs shown in Fig. 1. A complete unit, ready for operation, is illustrated in Fig. 2.

Tests have shown that 0.3 watt can be pumped by this unit while the cold-junction temperature at 2 C in an ambient temperature of 22 C is maintained. This is with natural convection cooling on the hot-junction heat exchanger. As illustrated, the unit occupies a space of 2½ by 2 by 2 inches and weighs approximately 8 ounces. This is a practical device which well demonstrates the compactness possible with thermoelectric cooling. Even smaller units can be built with improved materials which are now available.

ELECTRONIC COMPONENT COOLERS

A LOGICAL EXTENSION and an excellent area of application for spot coolers is thermoelectric cooling of electronic equipment, especially semiconductor components and microminiature electronic equipment. Semiconductor components are limited in their use by their maximum operating temperatures. The temperature of germanium transistors, for example, must be kept below 65 C to insure reliable operation. Passive devices, such as forced-air or natural convection heat exchangers, are employed to limit the temperature rise of the component *above* ambient temperatures. Thermoelectric spot or small volume coolers enable the designer to create an artificial ambient for these critical components, an ambient whose temperature is *below* the ambient in which the total electronic equipment is contained.

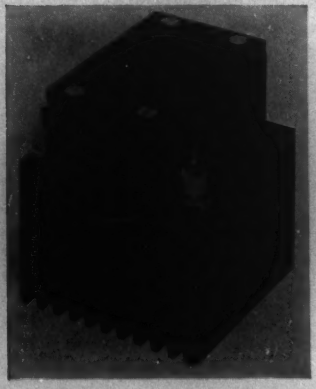


Fig. 2. Infrared-detector cooler.

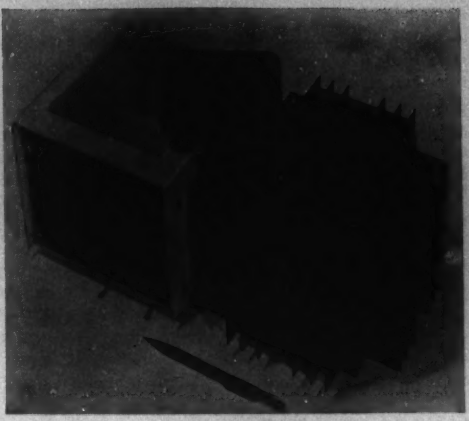


Fig. 3. Beaker cooler.

Reduction in size of electronic equipment leads to heat dissipation problems. Present microminiature electronic equipment, because of this acute problem of heat dissipation, are low-power devices. Further reduction in size or increase in power-handling capabilities becomes exceedingly difficult with present methods of heat transfer. Here then, is a fertile field of application for thermoelectric cooling. With its advantages of compactness, ease of integration with other electronic apparatus, and solid-state operation, thermoelectric cooling may be gainfully employed in the further development of microminiature electronic equipment.

THERMOELECTRIC BEAKER COOLER

AN EXCELLENT APPLICATION of thermoelectric cooling, for which there are many uses in a laboratory, is a small compact space or specimen cooler. Previously, dry ice or other temporary methods were used for cooling, or the specimen was precooled in a relatively large, centrally located refrigerator. Using thermoelectric cooling, a cooler and power supply can be designed into a size convenient for table-top use and, thus, be as easy to use as a hot plate. To demonstrate the feasibility of this application, a prototype cooler (see Fig. 3) capable of cooling or heating a chamber of a size to take a standard 50-milliliter breaker was built. Heating is obtained by simply reversing the current through the thermocouples. The chamber was constructed to be

watertight so that the device could be used without a beaker, if desired. A thermocouple is provided for measuring the temperature of the chamber or beaker. Overtemperature protection for the chamber, which protects it and the thermoelectric assembly from damage, is provided by a safety thermostat. The over-all dimensions of the device illustrated in Fig. 3 are 14½ inches long by 7⅝ inches wide, by 7¾ inches deep. The inner cooling chamber is approximately 2 inches in diameter and 1⅝ inches deep.

The space between the inner chamber and heat sinks is enclosed and filled with insulation. The power supply, located in the adjacent housing, furnishes full-wave rectified and filtered current at a low voltage to the thermocouples. The unit requires a 115-volt source of a-c power for operation. When the chamber is empty, its temperature can be reduced from an ambient of 80 to 25 F in about 15 minutes. In heating, it can be heated from 25 to 212 F in approximately 10 minutes.

Useful application of this device and similar units in this size range include the cooling or freezing of specimens for microscopy, the cooling of transistors or diodes for stabilizing characteristics during measurement or in circuitry, and the cooling of solids, liquids, or gases in small volume where low cost, ease of operation, and simplicity of apparatus are necessary or desirable.

A TEMPERATURE-CONTROLLED SPACE

THE ABILITY either to heat or cool simply by reversing current through the thermocouples makes thermoelectric cooling ideally suited for temperature-control applications. An early example of a thermoelectric temperature-controlled space is shown in Fig. 4. The volume of this cooler is 2 cubic inches. The thermoelectric system consists of a group of thermoelectric couples connected in series electrically across a d-c power supply, and in parallel thermally between the inside container and the external heat exchangers. The space between the central structure and the heat exchangers which make the external walls is filled with thermal insulation to reduce heat leakage into the inner container.

Temperature control of the space is achieved by the use of a thermistor bridge, a vacuum-tube amplifier, and a reversing relay. The temperature-sensing thermistor is directly attached to the inner chamber. The control rheostat which is in series electrically with the thermistor is located at the base of the cooler. The fixed resistors of the bridge are located in the remaining branch. The output of the bridge is amplified and fed to an a-c comparator. The output of the a-c comparator stage is fed to a third stage, where it is amplified. The output of the third stage controls the reversing relay which, in turn, controls the direction of the direct current through the thermoelectric couples. By varying the position of the rheostat arm, the temperature of the inner container at which the bridge balances can be varied. The power supply for this device is a conventional full-wave center-tapped rectifier type with a series choke filter. The percentage of ripple in the output current is maintained at 10% or less.

The over-all size of the thermoelectric unit of the device, exclusive of the mounting base, is 5⅛ by 4½ inches. The temperature control and d-c power supply are located in the adjacent cabinet. The unit operates from a single-phase source of 115-volt 60-cycle power.

In the cooling mode, the device will maintain a 40 F inner space temperature in an 85 F ambient with an additional 2-watt internal load. In the heating mode (that is, when the internal temperature is higher than ambient), the control system reverses the direction of current through the thermoelectric circuit, causing the junctions in contact with the inside container to dissipate heat (hot junctions) and those in contact with the finned heat exchangers to be heat absorbers (cold junctions). It should be noted at this point that in heating applications the coefficient of performance of a thermoelectric system is greater than unity. Maximum temperature attainable in the heating mode is limited by the control system to 140 F.

Although small in volume capacity, this early unit demonstrates quite well the potential use of thermoelectric cooling and heating in controlling the temperature of a small space. Many applications exist in the electronics industry for such a device. Continuing improvements in thermoelectric materials make it possible to get more cooling from fewer elements or construct larger units, thereby extending the range of application.

BIOLOGICAL TEMPERATURE CHAMBER

OFTEN the need arises in a scientific laboratory for a temperature-controlled environment. Ovens are used to provide environments at temperatures above room temperature. Temperatures below room temperature must be attained by some means of refrigeration. Temperature chambers capable of maintaining temperatures below or above room ambients are available. Heating or cooling in these units is usually obtained by combining mechanical refrigeration with electrical resistance heating.

Here again is a good application for thermoelectric

Fig. 4. A 2-inch temperature-controlled unit and supply.

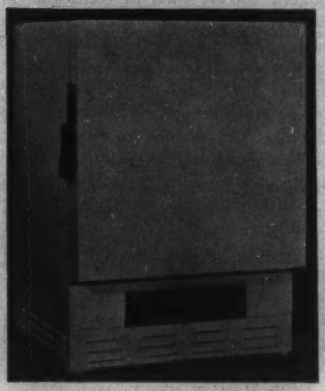


Fig. 5. Biological temperature chamber.

heating and cooling. A thermoelectric unit with its ability to heat or cool, offers the advantages of simplicity of operation and, in many instances, the additional advantages of freedom from moving parts and silent operation. A thermoelectric device which has been developed for use in the medical or biological laboratory is the biological temperature chamber shown in Fig. 5.

The available volume or working space within the inner chamber of this device is 3.1 cubic feet. The thermoelectric assembly and its control are capable of maintaining the temperature of the inner chamber to within ± 1 degree F of any temperature setting within the control range of 32 to 200 F.

The thermoelectric assembly of this unit is located between the back walls of the inner chamber and external cabinet. The assembly contains a number of couples which are in series electrically and in parallel thermally between the inside and external heat exchangers. Heat transfer between the thermocouples and the air within the chamber is accomplished with the use of a small, compact wire-mesh heat exchanger and forced air flow. The thermocouples are electrically isolated from the inside heat exchanger by hard-anodizing the hot-junction contact surface of the heat-exchanger base plate. Use of a forced air flow also insures uniform temperatures within the chamber. Forced air flow is obtained by the use of a small blower located in the floor of the inside chamber. Heat leakage from the blower motor was reduced by locating it outside of the insulating blanket around the inner chamber.

The hot junctions (in the cooling mode of operation) of the thermocouples are directly connected to individual finned heat exchangers which serve as electrical connectors as well as heat dissipators. The intervening space between the couple and heat exchangers is filled with foamed polyurethane insulation. The entire thermoelectric assembly is supported from the inside heat exchanger, which is directly connected to the back wall of the inner chamber.

The temperature control used in the biological temperature chamber is identical to the control described in the section entitled "A Temperature-Controlled Space." Although presently regulating temperatures to within ± 1 degree F of the desired setting, this control is capable of maintaining the chamber temperature to within ± 0.5 degree F of the desired temperature. The power supply for the unit's thermoelectric assembly is a conventional full-wave center-tapped rectifier supply employing a step-down transformer and an *L-C* filter. Maximum ripple in the output current of the supply is 10%. The chamber is designed to operate on conventional 115-volt sources of a-c power. The temperature control, power supply, and blowers are located in the base of the unit. As shown in Fig. 5, control of the biological temperature chamber is simple, being only an ON-OFF switch and a temperature control dial.

THERMOELECTRIC AIR CONDITIONER–HEATER–REFRIGERATOR

WESTINGHOUSE, under the sponsorship of the U. S. Navy, has undertaken the development of the largest device using thermoelectric cooling and heating being developed today. This experimental 3-purpose unit being built for the Navy will have these thermoelectric components:

1. A central thermoelectric air-conditioning unit which supplies chilled water that will be pumped to a standard Navy unit space cooler. The capacity of the unit is 12,000 Btu per hour. The heat removed in chilling the circulating water can be used for space heating or can be dumped as waste heat into sea water.
2. A central thermoelectric heater which supplies heated water to a standard Navy unit space heater.
3. A 2-cubic-foot refrigerator–freezer which can maintain a temperature of zero degrees F continuously.

These three units are being designed to be capable of independent operation. Each unit will be built up of identical thermoelectric elements, or modules, which can be individually removed and replaced, or can act as building blocks for a thermoelectric system of larger size.

The entire unit will conform to Navy Department practice, and the best available thermoelectric materials and fabrication techniques will be used in its construction. The Navy will use this experimental unit to test the suitability of thermoelectricity for air conditioning and refrigeration on ships.

THERMOELECTRICALLY AIR-CONDITIONED SUIT

UNDER CONTRACT with the U. S. Navy, Westinghouse is developing a thermoelectric suit air conditioner. This unit is being developed for the Clothing and Textile Division of the U. S. Naval Supply Research and Development Facility, Bayonne, N. J., where it will be built into an experimental "lightweight, impermeable, insulated, personnel protective garment."

The complete air conditioner will consist of three main components; a thermoelectric cooling and heating unit, a lightweight battery power supply, and a blower

system to circulate the air inside the suit. The air conditioner is being designed to maintain the temperature in the suit at 80 F in ambient temperatures ranging from —40 to 135 F.

The conditioned air inside the suit will not be used for breathing purposes. A separate external system, provided by the Government, will supply air for respiration. Efficient, lightweight, rechargeable batteries, having sufficient storage capacity to operate the suit for a minimum of one hour, will provide power for the air conditioner. The suit is also being designed so that it can be plugged into an external power source when time and conditions warrant.

CONCLUSIONS

PRACTICAL thermoelectric refrigeration has become firmly established with the development of thermoelectric semiconductor materials. Offering small size, simplicity of construction and operation, and reliability, thermoelectric coolers are solving a continuously growing number of cooling applications, particularly in the electronics industry. Electronic cooling applications include spot coolers for a variety of detector cells, component coolers such as transistor and diode coolers, instrument coolers, and constant-temperature devices such as crystal ovens. Medical applications include specimen cooler–freezers, blood coolers, portable refrigerators for transportation of blood, and constant-temperature devices such as the biological temperature chamber. Commercial applications include home water coolers, portable refrigerators, hostess carts, and similar applications involving small-volume cooling.

Continuous improvements in thermoelectric semiconductor materials continues to increase the number of applications in which practical thermoelectric refrigeration can be employed. The design and the development of these thermoelectric devices with their associated heat exchangers, power supplies, and control offer an interesting challenge to the engineer in what is now a firmly established and rapidly growing field.

REFERENCES

1. Thermoelectric Spot Coolant Applications, E. W. Frantti, R. S. Lackey, H. A. Wagner. *Wescon Convention Record*, Institute of Radio Engineers, New York, N. Y., pt. 6, 1959.

2. Applications of Thermoelectric Cooling and Heating, R. S. Lackey, J. D. Mess, E. Somers. *Refrigerating Engineering*, New York, N. Y., Dec. 1958.

Project EHV

First shipment of aluminum members for a structure to serve the world's highest-voltage electric power line has been made by Aluminum Company of America (Alcoa). (Partial preassembly of one portion is shown in photo.) When assembled, they will form the world's largest aluminum substation.

The aluminum components will comprise the North Substation of the pioneering "Project EHV" (extra high voltage) power line. This structure is one of several Alcoa contributions to the line, in co-operation with Project EHV sponsor, General Electric Company.

Now being constructed in western Massachusetts, the Project EHV line will carry higher voltages than ever before transmitted. It will be used to acquire technical information necessary to help the electrical industry supply economically America's vast anticipated future power needs.

Project EHV will explore the implications of tomorrow's power transmission voltages, looking to a future transmission voltage 3 or more times today's typical 220 kv. As such, it will comprise a collection of superlatives of equipment and facility size and capacity. The Alcoa substation is no exception.

The substation will be flanked by two portal-type (visually, a giant inverted "U") aluminum tower structures. Incoming utility power lines will reach a 42-foot-wide tower. Starting point of the experimental transmission line is a mammoth aluminum structure, comprising 68-foot-high vertical members supporting a 123-foot span.

The two towers, and the host of columns and structures within the substation between, are lattice-type assemblies of aluminum structural angles joined with aluminum bolts. Virtually all materials used in the substation are of aluminum.

In addition to the North Substation, Alcoa is supplying for Project EHV all conductors and accessories, an aluminum transmission tower, and lightning collector spires for 18 towers. General Electric Company expects initial operation of the line late in the Summer of 1960.

Asynchronous Multiplexing

J. E. TAYLOR

MULTIPLEXING is the process by which two or more signals are combined for transmission over a common medium. Asynchronous multiplexing is any such process which does not require the various transmitters to be synchronized with each other. Thus, frequency division is such a system, but is considered here only for a comparison standard.

Among the problems of asynchronous multiplexing with nonorthogonal (energywise) channels are: (1) specifying optimum systems; (2) placing bounds on the performance of asynchronous systems; and (3) analyzing specific systems in terms of capability of providing access to the communication medium for many stations, and also the information transmission rate capabilities. The discussions given represent the work of many others besides the present author.

The first problem has been studied from the point of view of finding optimum probability density distributions for two continuous band-limited signals additively mixed in a common medium perturbed by white band-limited gaussian noise. No general solution to the problem of maximizing the total system rate of transmission has been found. However, signals having gaussian statistics give a stationary rate

$$R/W = \log_2\left(1+\frac{S_x}{S_y+N_n}\right)\left(1+\frac{S_y}{S_x+N_n}\right) \text{ bits per second per cps}$$

where S_x, S_y and N_n are respectively the second moments of the (signal) variables transmitted x and y, and n the noise variable. W is the system bandwidth.

The second problem has been studied from the point of view of finding the theoretical limitations on the transmission rates of some general nonorthogonal systems. There are assumptions that the coding of the individual channel's signals is such that the interference in one channel of the system due to the signals in all other channels is exactly white band-limited gaussian noise. The most general such nonorthogonal system is assumed further to require each channel to use, and accept noise from, the entire frequency-time space available to the system. A more restricted system is also considered; it requires the coding of the signals to be such that one channel uses, and accepts noise from, only a fraction of the total frequency-time space available to the system. Such a system is termed "channel synchronized." Information transmission rates for such systems, assuming all channels are identical, were calculated as functions of various parameters: signal-to-noise power ratio, number of channel assignments made, and fraction of the total system frequency-time utilized by each channel. In regions of interest for the values of these parameters, the channel synchronized system capacity is of the order of one tenth that of the general nonorthogonal asynchronous system.

A comparison of the general nonorthogonal system with an optimally coded orthogonal system using frequency-division multiplexing shows that for low signal-to-noise power ratio, the relative efficiency of the nonorthogonal system is high, while at high signal-to-noise power ratio—yet low signal-to-interference ratio for the nonorthogonal system—the relative efficiency of the nonorthogonal system is low. To sum up, it can be said that nonorthogonal systems of multiplexing will require from 5 to 50 times as much bandwidth to transmit information at the same rate as an equivalent orthogonal (e.g. frequency division) multiplexing system. This is the price paid for the flexibility of the nonorthogonal systems.

Studies were made which determine bounds on the number of channel assignments possible using fixed block length coding schemes to specify the various channel waveforms.

In one such system studied, matched filtering would be used for separating the various channel waveforms. The waveforms considered are described by binary sequences. The analysis was extended to 7-digit sequences, but cannot be extended successfully to much longer sequences which would be of interest. For a threshold level of two units less than maximum, one third of all sequences can be used for channel assignments, while for lower threshold levels, the number of assignments falls rapidly to zero. The number of channel assignments which can be made by random choice of long binary sequences has been calculated for a system which is essentially a quantized matched filter. Assuming operation at high signal-to-interference and signal-to-noise ratios, it is found that many channel assignments can be made with 50 to 100 digit codes. To hold interference to tolerable levels will, of course, require much longer codes.

The results of several independent coding theory analyses which have recently appeared show that fixed block length coding schemes can be used to specify a large number of channels, but the systems considered still imply comparatively low rates of transmission of information.

An experimental study of a simulated 2-channel asynchronous multiplexing system using delta modulation was made.

Digest of paper 59-1146, recommended by the AIEE Communication Theory Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Fall General Meeting, Chicago, Ill., Oct. 11-16, 1959. Published in AIEE *Communication and Electronics*, Jan. 1960, pp. 1054-62.

J. E. Taylor is with the General Electric Company, Schenectady, N.Y.

Formation of Proposed Institute Groups

W. A. LEWIS
FELLOW AIEE

A brief description of the plan, recently approved by the Board of Directors of the AIEE, for the formation of Institute Groups. These groups are intended to serve members of the Institute having a common interest, either along technical or more general lines.

IN December 1957, Past President W. J. Barrett appointed a Special Task Force on Institute Activities and Organization, to survey the needs of the Institute and to make recommendations for basic improvements in the Institute organization and activities. This Task Force has rendered its report to the Board of Directors, and the recommendations contained therein have been approved by the Board, either as submitted, or after further consideration by the Task Force and the Planning and Co-ordination Committee. Steps to implement these recommendations have been started, and further steps will be taken. This article will be concerned with only one of those recommendations, the formation of Institute Groups. It is self-evident that one of the main purposes of the Institute is to facilitate the kinds of interests and activities that will best serve the members of the Institute, and will promote the profession of electrical engineering. One of the most effective means of doing this is to provide meetings at which technical discussion may take place, and papers on technical and general subjects of interest to the members can be presented and discussed. Study of recent Institute activity has shown that there has been great interest in the formation of local Section groups directed toward particular purposes. Also, on a nationwide basis, there has been a growing interest in Special Technical Conferences of Institute members devoted to the consideration of particular technical subjects. Although a member of the Institute might find his interest represented very closely by the subject matter at a particular Special Technical Conference, or by a local Section group, he has had little opportunity to participate in the conduct of these activities unless he has been a member of an Institute committee, active in the conduct of the particular work. Thus, he has not had opportunity either for close affiliation with the work or to voice his opinion in the conduct of the activity. It has not been easy for him to make effective suggestions regarding the formation of new activities or the conduct of those which exist.

A special article recommended for publication by the Special Task Force on Institute Activities and Organization.

W. A. Lewis is chairman, Special Task Force on Institute Activities and Organization. He is with the Illinois Institute of Technology, Chicago, Ill.

In recognition of this situation, the Special Task Force has recommended that facilities be provided for the formation of groups on an Institute-wide basis that can be directed to any of the technical or general activities of the Institute, as the members themselves may desire. Thus, the present proposal provides for the formation of Institute Groups in any recognized field of Institute activity, but does not require the formation of any such group unless the members themselves wish to set it up.

GROUPS BASED ON COMMITTEE STRUCTURE

THE Special Task Force believes that the strength of the Institute's technical activity has resulted from the technical and general committees of the Institute. They have been responsible for the programs at technical sessions or at Special Technical Conferences, have undertaken technical activities judged desirable, have prepared reports concerning appropriate practices, and have developed many Institute and American Standards. Any plan of reorganization should try to take advantage of the strength of the present organization, and should utilize as far as possible the good features of the present structure. With this in mind, it has been proposed that the new Institute Groups should be formed around the subject matter of the individual committees, either technical or general. At the present time, there are 50 technical committees organized into the 6 technical divisions of the Technical Operations Department, as well as four general committees of the Technical Operations Department, and the Research, Safety, and Standards Committees. In addition, there are committees in some of the other departments, such as the Education Committee and the Management Committee of the Professional Development and Recognition Department, that might very well wish to form Institute Groups concerned with their activities.

It is not expected that an Institute Group would be formed around each of these approximately 60 committees, but provisions will be made that wherever the members themselves desire, a Group can be formed around any of the committees. All of the groups will not be formed at the same time; development will be gradual. In areas where rapid change is occurring, Institute members will find greater need for organization, to promote closer contacts, facilitate the exchange of technical information, and direct the technical program of the Institute along lines that will be most fruitful. Membership in a group will give each member of the Institute an opportunity for developing a sense of "belonging" to his professional organization. A study of

other organizations of engineers suggests that group activity of this type can be particularly valuable.

Once an Institute Group is fully organized, it is expected that the technical program, participation in general meetings, establishment of Special Technical Conferences, and assistance to local Sections in the conduct of their technical activities will all be carried out under the name of the responsible Institute Group. However, since the groups will be relatively large, it will not be feasible for them to act as a whole, and activities must be delegated to a central committee. Therefore, existing technical committees will continue, but their function will be diverted from that of complete responsbility for their own activities to that of becoming the steering and supervising committees for the activities of the appropriate group. Under the new plan, each member may join the group of his choice, or as many groups as his interests may suggest. Under the proposed plan, opportunity will be afforded for the members to indicate the groups they would like to see formed, and apply for membership in them. When the number of bona fide applications reaches an established minimum, the Group will be formed, and put in operation. To ensure that a group is formed only when there is evidence of sufficient interest, it is proposed that a minimum number of applications be established. This number is, of course, subject to change as experience develops, but the Special Task Force has proposed that a minimum of 50 applications be required before a group is formed.

ORGANIZATIONAL FEATURES

IT IS PROPOSED that each Institute Group should hold at least one business meeting a year at a general meeting, at an appropriate Special Technical Conference, or at an appropriate district meeting. During the meeting, the officers of the Group, who also will be the officers of the corresponding committee, should outline plans for the activities of the Group and its committee, and report on work in progress and recently completed. They should also report on the subjects of proposed technical sessions, Special Technical Conferences and other meetings, standards activity in progress, and other work of interest to the group members. Members of the Group should be afforded opportunity to discuss all of the material presented, and to make suggestions for modifications or additions to the activity to be undertaken and for personnel to carry it out. Members of the Group will be given opportunity to suggest candidates for future membership on the committee. It will be appropriate for them to volunteer for committee activity when they believe they can be of service. Minutes of such Group meetings will be kept, and copies of these minutes, as well as copies of the minutes of meetings of the corresponding committee, will be distributed to all members of the group. Several other detailed steps are being proposed which are intended to make the activities of the Groups of greater significance to the Institute as a whole, and to the individual members of the Group. Although it is proposed initially that the officers of the Group and of the corresponding committee be appointed, provision will be made, if members desire it, that when the Group reaches a substantial size, it may elect its own officers.

It is expected that the organization of Institute Groups along technical lines will further increase the interest in corresponding Section technical groups, and perhaps encourage the alignment of the local groups along the same lines. Provisions will then be made for closer liaison between the Section technical groups and the corresponding Institute Groups on a nationwide basis.

In the proposal, it has been suggested that the Groups be formed around the activities of the existing technical committees, in the belief that the technical field of electrical engineering is well covered by the existing committees, and there would be little to be gained by setting up the groups around any other alignment of subject matter. However, this certainly does not mean that the present committee organization cannot be modified, subdivided, combined, or adapted, as may be most suitable to meet the changing needs of the membership.

The operation of the proposed group plan is to be made the responsibility of the corresponding department of the Institute. Since most of the activities proposed will be of a technical nature, the major portion of the new program will come under the jurisdiction of the Technical Operations Department. Other departments, such as the Professional Development and Recognition Department, will participate as groups are organized within their departments. The Board of Directors has referred the whole plan to the respective departments, and requested them to make the appropriate plans to inaugurate the Institute Groups as soon as possible. Much detailed planning remains to be done, and it is not yet possible to specify a date for the establishment of the first group. However, it seems highly probable that the plans can be sufficiently advanced to permit the formation of the Groups most urgently desired during the 1960-61 administrative year of the Institute.

The Special Task Force believes that this proposed plan is an important step in molding the Institute to serve its members better, and sincerely hopes that it will be a success. Meanwhile, all members of the Institute are asked to co-operate in the project by lending their support to the program as a whole and by participating actively in the formation and operation of groups in their areas of special interest. Each AIEE member can receive benefits from the Institute only if he participates actively in its work. The Special Task Force is firmly convinced that the greatest success of the Institute will come in providing ample opportunity for the members to help themselves.

A more detailed and comprehensive description of the plan for Institute Groups will appear in a subsequent issue of *Electrical Engineering*, and the details of the plan, as it is unfolded, will be published in later issues.

Why We Are What We Are

G. C. BAXTER ROWE
MEMBER AIEE

The range of subject matter in the broad field of electrical/electronic engineering is constantly widening. The reasoning behind and necessity for *Electrical Engineering*'s "horizontal" approach are explained.

HORIZONTAL . . . It is assumed that readers of *Electrical Engineering* are familiar with Mr. Webster's definition of the word, but it would be quite excusable if they do not know what that adjective means to an editor or advertising man. In magazine parlance, horizontal means covering all phases of a series of related subjects and markets in a particular field.

As an example of a horizontal publication, consider *Food Processing*, which deals with food plants' operations, the chemical aspects of food, research and development, cold-storage plants, etc., in fact, the entire gamut of food preparation except cooking.

Now consider the opposite phase—the vertical publications. In this same food field, there are technical publications devoted solely to baking, bottling, brewing, canning, dairy products, fish, grain and feed, groceries, ice cream, meats, etc. Each is aimed at a single item or field of one of America's greatest industries.

In the electrical/electronic industry, there are parallel instances. There are magazines devoted only to those interested in the production of electric power, in the design of electronic equipment, in the engineering of automatic controls, in telephone research. In practically any phase of the industry you can name, there is a vertical magazine interested in but one segment of the industry.

Then there is the opposite side of the coin: the publication which covers all facets of the electrical/electronic industry. You may not realize it, but this is the function of your publication: *Electrical Engineering*.

A VARIETY OF TECHNICAL INTERESTS

WHY IS IT HORIZONTAL? The answer lies in the varied technical interests of you and your fellow members. If you are unfamiliar with how wide these interests are, glance at the names of the Institute's Technical Committees and you will see how your organization is divided. There are 50 Technical Committees operating within the six basic Technical Divisions covering fields ranging all the way from large rotating machinery to minute solid-state devices. In other words, you and your associates have interests from A to Z—from alternators to zener diodes!

The AIEE has been accused of being a "power" organization because so many of its members are in the utility field. Granted that some 30% are, and that we must also include those who make the products sold to utilities. But have you ever stopped to think how many different phases of that field there are? Have you considered to what extent electronics is a basic and integral part of power?

The telemetering engineer certainly plies his trade in the remote control of power lines and substations. How about analog and digital computers? Aren't they used extensively in the power field to solve many engineering problems? Isn't the communication field tied in directly with power lines and their operations, both telephone and telegraph? The use of closed-circuit television is becoming more common in the power field. Microwaves, all sorts of metering devices . . . the list of allied electrical/electronic interests is far too long for these columns. The fact is obvious to anyone who gives it any thought that without the electronic engineer, today's power engineer would have hard sledding—and it is so reflected in the Institute's membership.

It is to serve this over-all membership interest that the editor of *Electrical Engineering* strives. That is why you will find articles in its pages which may seem far from your particular line of work, but when you get right down to it, are they so far away? Shouldn't you be interested in what is going on not only in your field but in others as well? A design problem solved by a utility may point equally to a solution in a steel plant, a radar station, a telephone company, or an office building.

A wide editorial approach in this day and age is necessary because all electrical engineering subjects are interrelated. You as an engineer must have a broad outlook and know something about the many ramifications not only of your own particular field but of all others within the industry. And that is what the editor is giving you in these pages.

MONTHLY QUESTIONNAIRE

TO HELP YOUR EDITOR determine what you want to read, a questionnaire has been sent each month for more than 4 years to 1,000 different AIEE member-readers in the United States, asking them to evaluate the articles in a particular issue, to indicate their preferences for the several departments of the magazine, and to make suggestions. It may be of interest that since November 1955, the average return of the completed questionnaires has been approximately 22% each month and nearly every one returned has contained suggestions

G. C. Baxter Rowe is associate editor, *Electrical Engineering*.

and opinions as to how the magazine could be improved.

These suggestions which have been received cover as broad a field as does the magazine itself; they range from "It's good as is; don't change it at all" to "It's all wrong in every way and I'll tell you why." Each of the editorial staff looks over the returned questionnaires for clues to your needs. Over the years a pattern of answers and suggestions has evolved.

From college professors and workers in the research field come the suggestions: "The magazine should be more technical. . . . Give us more mathematical developments of theory." The engineer who is in a managerial position says there is too much mathematics now in the articles: "Give us less theory and more general interest articles." The man just graduated from an engineering school wants articles that will help him get along in his field. In short, from a man's interest and work come the suggestions for articles which will best help him.

A BROAD APPROACH

NOW HERE IS THE CRUX of the matter. Since it is virtually impossible to please all readers of a publication with horizontal appeal, what can the editor of *Electrical Engineering* offer you that vertical magazines cannot?

For one thing, you can be kept aware of what is happening throughout the industry rather than in just one segment of it. Why turn your back on what is occurring in the telephone field just because you happen to be a specialist in underground cables for a utility? Both fields have common interests in such problems as insulation, protection devices, conduits, humidity, and the like.

So much for the technical side. What about the common interests of all electrical engineers? If you happen to be a microwave specialist, there is no reason to think that you are, or should be, set apart professionally from a nuclear control engineer or a substation engineer or the man who has charge of the rolling stock of the Boston Transit System. When you were studying engineering in school, everyone's interests were the same: electrical engineering. It was only after you graduated that you began to specialize. But no matter how far "up the tree" you have progressed, the trunk and roots are still electrical engineering. Moreover, *Electrical Engineering* is still the spokesman for your profession—not in any narrow sense, but in as wide a sense as the 50 Technical Committees can make it.

This leads to what your editor is trying to do to make *Electrical Engineering* a better publication for you. The idea is to broaden the scope and its contents, not narrow them. If you want specific technical data, you will find it in ample quantity in your three bimonthly publications. What the editor would like to give you are more general interest articles.

He would like to bring you more tutorial articles so that you will not have to thrash around in your mind to arrive at answers to problems that were so clear and simple on graduation day.

He wants to give you more articles on interesting applications and uses of products, systems, and equipment, for it is well known that the germ of an idea can circulate and stimulate useful thinking in other areas beside the one for which it was designed.

He wants to give you more articles dealing with managerial problems, since, as you progress onwards and upwards in your career, you will be given more responsibility in the supervision of men and engineers.

It is the editor's philosophy to further electrical engineering as a profession and continue to raise its standards to that level which it richly deserves.

In short, *Electrical Engineering* is the spokesman for your profession, and your editor is trying every way in his power to design it in that likeness. It follows, of course, that its success largely depends upon your support.

Contoured Reflectors

Key to optimum performance in lighting is a top-quality reflector. The Edwin F. Guth Company, St. Louis, Mo., maintains this quality by using Formica laminated plastic spinning chucks in the manufacture of a large line of incandescent lighting fixtures. Made from Formica *S-52*, a paper-phenolic laminate grade, the chucks shape aluminum reflectors on spin lathes. The extremely smooth, hard surface of the *S-52* chuck results in perfectly contoured reflectors with a minimum of visible, light-deterring marks on the inner surfaces.

Industrial Computers for Tank Farm Inventory Control and Data Handling

E. B. TURNER
MEMBER AIEE

R. J. NOORDA
ASSOCIATE MEMBER AIEE

The use of an industrial computer of the general-purpose, digital, stored-program type for the accumulation of data from tank farm storage facilities and its automatic manipulation into forms suitable for inventory control and further processing.

THE PROBLEM associated with tank farm operation is that of physically assembling information scattered over a relatively large geographical area (several square miles) correcting, evaluating, and correlating this data into a form which is then interpretable into operating guides and accounting or business information. To illustrate how an industrial computer system (Fig. 1) would operate in this application, a hypothetical tank farm has been assumed.

The tank farm handles 20 different shippers, each

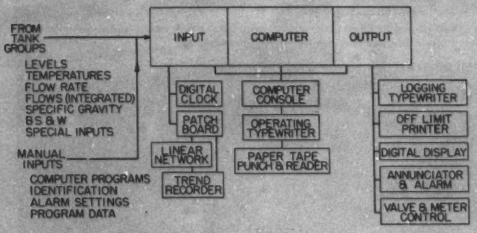


Fig. 1. Block diagram of computer system for tank farm inventory control and data handling.

of which averages 5 different products. The tank farm consists of 150 tanks of various sizes ranging from 20,000 barrels to 200,000 barrels. Since these tanks were installed over a period of time, they are of various types and utilize various forms of tank level gauging. Each tank has a means of detecting temperature as well as tank level. This tank farm is representative of the complexity associated with larger installations.

The information which is available to the data-handling system consequently consists of the following: (1) Tank level height, (2) Tank temperature, (3) Product identity, (4) Flow rate, (5) Integrated flow, and (6) BS&W (basic sediment and water).

Supplemental information which is required to be able to interpret the available data is as follows: (1) Tank-strapping data, and (2) Temperature correction factor, which is necessarily associated with product identity.

Product identity will be handled either by specific gravity measurement or manual input identification. Since the various tanks in this tank farm will be utilized for similar products and may not be assigned continuously to one product of one shipper, adaptability of the data-handling system to flexible identification is necessary.

DATA AVAILABILITY

THE DATA WILL BE AVAILABLE in different forms due to the age difference in equipment utilized as well as to the physical sizing of the equipment. Basically, the tank level readings will be available with two types of inputs—analog and digital. The digital data will be in at least two forms; straight decimal, in which the bits of information transmitted are counted to determine the quantity involved, and binary coded decimal, in which the bits are arranged in coded form to determine the quantity information.

Since the data-handling system is taking information from existing tank gauging equipment, it cannot improve the accuracy of the basic tank gauging equipment. For digital information, no additional inaccuracy will be added as the data (after conversion to straight binary coding) will be handled directly. For analog inputs, the analog-to-digital portion of the data acquisition system is usually more accurate ($\pm 0.25\%$) than the existing analog gauge. Regardless of the type of input (Fig. 2), the data is transformed to straight binary coded form for the computer operations.

The tank level information must be associated with the average tank temperature taken at approximately the same time. The types of tank temperature measurement which are available provide the data usually in analog form. With the information on tank level, tank temperature, product identity, and tank identity in the computer memory, it is necessary to make the necessary correction for temperature and to consult the tank-strapping data to change the tank level reading into corrected volume.

It is a well-known fact that tanks are not completely symmetrical and, consequently, the tank-strapping data is not an exact straight line. However, the physical size of the tank and its general configuration precludes the possibility of abrupt discontinuities in the tank-strapping data. If it were necessary to store volume data

E. B. Turner is with the General Electric Company, Schenectady, N. Y.; R. J. Noorda is with the General Electric Company, Phoenix, Ariz.

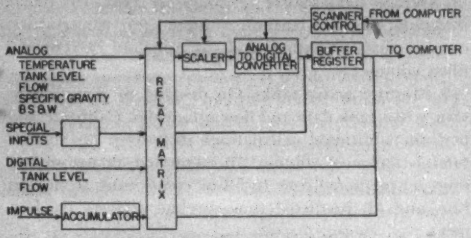


Fig. 2. Data input to the computer system.

based upon every 1/16 or 1/8 inch of tank height, the memory storage requirements would be both large and uneconomical. This does not preclude further examination of the problem.

Referring to Table I, it can be seen that by utilizing straight line approximation as often as necessary over the height of the tank, it is possible to simulate the tank volume curve. The number of slopes required are a result of the allowable deviation. In Table I, 1/16 of an inch is equivalent to 7.28 barrels. Utilizing three slopes, the maximum deviation is less than three barrels or an accuracy of better than 1/32 of an inch. It is relatively easy to handle as many slopes as are required to provide the necessary accuracy and still keep memory storage and speed of operation within reasonable limits.

OPERATING INFORMATION AND GUIDES

For tank farm operation, the data-handling system would perform periodic logging as well as continuously monitoring all active tanks and tenders. From a tank farm of this size, there will usually be several outlets and consequently several tanks filling and emptying simultaneously. Monitoring of active tanks and tenders would provide such information as when a delivery is expected to terminate. With the data available, supplemented by manual inputs in form of tender size, etc., the data-handling system will be used to integrate and accumulate data from the various flow-rate sources. Knowing the volume in a tank at any given time and the flow rate in or out, the data-handling system would periodically predict the empty or fill-time remaining.

With the information available from the hourly log, the tank farm operator has knowledge of the amount of product in a given tank, as well as knowing what space is available within any given tank. He may desire to obtain a summary based upon several possible combinations, for example:

1. Summary of a given shipper's specific product.
2. Summary of tank volume remaining or tank volume available in all tanks of a given shipper's product.
3. A search to determine which tank containing a given shipper's product has sufficient space available for a given volume of delivery expected.
4. Search for a tank with sufficient volume of a given product to meet a delivery requirement.

Since all of this is operating data and information, this would be carried on a separate typewriter which would be called the "operating" typewriter. This "operating" typewriter would provide a means of inserting the desired operations into the computer by means of a paper tape reader. The paper tape reader would actuate the typewriter to prove out and provide a record of the information requested of the data-handling system. Since this would be an unwieldy form of operation where the same request is made frequently, the computer system would have several subprograms stored in the memory which would be actuated by manual selection of the operator (Fig. 3). For example, summary of a given shipper's products contained in the tank farm by product may be a common requirement and, as such, the program for searching through the tank storage data for shipper identity would be a subprogram carried in the computer. The same would be true of a search for a tank of a given shipper and product with sufficient capacity to hold required tender size. There are many examples of this and the amount of flexibility is limited only by the imagination and requirements of the tank farm operator.

The following section will illustrate how the computer would be applied in the tank farm data-handling system. This planning and programming approach

Table I. Simulation of Tank Volume Curve

Height (feet)	Tank Strapping Data (barrels)	Volume per Linear Slope (barrels)	Error-(barrels) Linear Volume-Strapping Data
4	1,314.45	1,314.45	0.0
Slope in barrels per foot = 1,399.60			
5	2,712.19	2,714.05	+1.86
6	4,111.68	4,113.65	+1.97
7	5,512.11	5,513.25	+1.14
8	6,912.28	6,912.85	+0.57
9	8,312.46	8,312.45	−0.01
10	9,712.63	9,712.05	−0.58
11	11,112.80	11,111.65	−1.15
12	12,512.78	12,511.25	−1.53
13	13,712.39	13,910.85	−1.54
14	15,312.00	15,310.45	−1.55
15	16,711.61	16,710.05	−1.56
16	18,111.22	18,109.75	−1.47
17	19,510.82	19,509.35	−1.47
18	20,910.43	20,908.95	−1.48
19	22,310.04	22,308.55	−1.49
20	23,709.63	23,708.15	−1.48
21	25,109.09	25,107.75	−1.34
22	26,508.34	26,507.35	−0.99
23	27,907.99	27,906.95	−1.04
24	29,307.20	29,306.55	−0.65
25	30,706.08	30,706.15	+0.07
26	32,104.95	32,105.75	+0.80
27	33,503.83	33,505.35	+1.52
Slope in barrels per foot = 1,398.00			
28	34,902.61	34,903.35	+0.74
29	36,301.09	36,301.35	+0.26
30	37,699.36	37,699.35	−0.01
31	39,097.62	39,097.35	−0.27
32	40,495.87	40,495.35	−0.52
33	41,894.02	41,893.35	−0.67
34	43,289.51	43,291.35	+1.84
35	44,687.76	44,689.35	+1.59
36	46,085.96	46,087.35	+1.39
Slope in barrels per foot = 1,397.00			
37	47,481.40	47,484.35	+2.95
38	48,879.65	48,881.35	+1.70
39	50,277.90	50,278.35	+0.45
40	51,676.03	51,675.35	−0.68
41	53,074.11	53,072.35	−1.76
42	54,470.88	54,469.35	−1.53
43	55,868.49	55,866.35	−2.14

Fig. 3. Operator at computer console. Paper tape reader is at operator's left and operating typewriter can be seen in right background.

would be utilized in any application for an industrial computer of the general-purpose, digital, stored-program type.

COMPUTER ORGANIZATION

THE SPEED of the modern digital computer is so high, it gives the impression that many functions or programs are carried out simultaneously. This, of course, is not so. The proper utilization of the computer requires that organizational procedure be programmed into the computer so that all things may be done either with periodicity or on the operator's choice of order.

Major Functions or Programs. To organize the computer, we first list all the major functions which are required. In the case of the tank farm, these functions will be as follows:

1. Scan all tank data including tank level, temperatures, product identification, flow rates, integrated flows.

2. Calibrate into correct engineering units where necessary and perform required calculations as follows: (a) average temperature readings per tank, (b) linear interpolation for current volume, (c) temperature-correct current volume, and (d) calculate current unfilled volume.

3. Monitor active tanks. On demand or periodically, scan active tank data and flow quantities. Calibrate and perform additional calculations including: (a) current rate of change of volume, (b) integrated change of volume, (c) predicted time to fill or empty tank at current rate, and (d) predicted time to close delivery or shipment.

4. Monitor active tanks to determine when full or empty, on demand or periodically.

5. Prepare following reports, on demand or periodically: (a) summary of given shipper's specific products in storage, (b) summary of tank volume available in all tanks of given shipper's product, (c) search for tank with space for delivery expected, and (d) search for tank with sufficient product to meet shipment required.

System Processor Description. In order physically to accomplish the functions listed, the computer system (Fig. 4) will consist of equipment of three classifications:

1. Input Unit. For the tank farm application, there are three types of data inputs to be processed by the system:

a. Analog inputs (voltages)—height indicators, temperatures (thermocouples), flow, specific gravity, and BS&W.

b. Digital inputs—height indicators, flow rates, and integrated flows.

c. Manual inputs—identification data, programming data, display selection, and alarm settings.

2. Central Processing Unit. This is the computer which selects incoming data, processes it, performs the necessary calculations, and provides the desired output data. These operations are performed in accordance with the various programs written for this application.

3. Output Unit. For this application, there would be two kinds of output information. For these, there would be provided one or more of the devices listed:

a. Operation guides, typewriters, paper tape punch, visual displays, alarms, and valve and meter control.

b. Accounting and business information, typewriters or teletypewriters, paper tape punch, and card punch.

Over-all Flow Chart. Since there are many functions (i.e programs) to be performed in this application, and since a digital computer can perform only one function at a time, it is necessary to assign priorities to these programs. This requires the introduction of an additional program, the "Executive Control Program." The "Executive Control Program" does not perform an

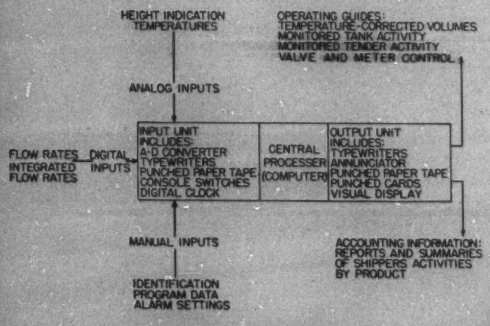


Fig. 4. System organization.

operating function. It directs and dispatches the operating programs, scheduling these programs in descending priority sequence. One possible priority assignment of the major programs follows: (1) on demand, prepare reports; (2) on demand, monitor active tanks; (3) on demand, monitor active tenders; (4) on demand, scan all tank data and print out temperature correct volumes; (5) periodically monitor active tanks; (6) periodically monitor active tenders; (7) periodically scan all tank data and print out temperature-correct volumes; (8) periodically prepare reports; and (9) periodically perform computer checking and diagnostics.

The over-all flow chart (Fig. 5) illustrates how the entire program is under the guidance of the "Executive Control Program" monitoring the operator's controls, the digital clock, and the individual functions to determine priority and sequence of the routines.

Time and Storage Requirements of Computer. In order to use the computer as outlined in the over-all flow chart, one must program each of the separate functions of Fig. 5 in detail. After this is complete, it is necessary to optimize the computer's performance in order to accomplish all the required functions as quickly and efficiently as possible. As an example of the programming procedure and the efficiency with which the computer works, we will consider the one function of scanning all tank data and calculating temperature-correct volumes.

The simplified flow chart for this routine is shown in Fig. 6. The speed with which the entire 150 tank farm data can be processed is limited to the speed with which the data can be scanned (10 points per second) and the results printed out (10 characters per second). These functions along with the computer calculations are overlapped so that the times are not additive. The time required per tank is slightly less than 3 seconds. This time is essentially imposed by control and operation of the printer.

It is estimated that memory capacity required to perform all the functions shown in Fig. 5 would be approximately 7,000 words for this 150 tank installation.

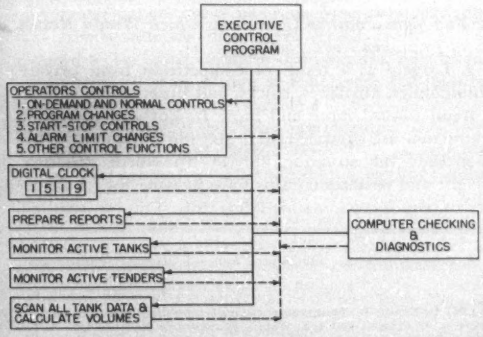


Fig. 5. Over-all flow chart.

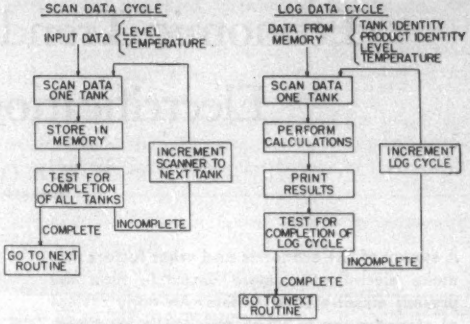


Fig. 6. Simplified flow chart for tank data processing.

This would be handled with a standard 8,000-word magnetic drum memory. If the number of programs were increased, a larger memory would be required. To provide for future program modification and growth, a 16,000-word drum initially equipped for 8,000-word storage would provide the necessary expansibility.

CONCLUSIONS

It is obvious that the reliance which is placed upon this computer in tank farm inventory and data-handling problems is such that the flexibility and reliability are of extreme importance. From this point of view, it is necessary to indicate how the computer itself must be designed for both of these requirements. The use of a magnetic drum memory insures the maximum reliability and integrity of the information being handled. Due to the basic magnetic drum principles, power outages or interruptions will not cause loss or alteration of stored data. This is essential when it is considered that in a general-purpose digital computer, both the information being handled and, more important, the program controlling the operations are stored in the memory. Reliability is further a function of the design and of the component equipments which are utilized in the design. Complete attendance to conservative design utilizing well-proven components as well as well-proven techniques insures that operation will be adequate for the reliability requirements.

Flexibility is a feature of general-purpose-type computer design. A special-purpose computer is defined as one which is not easily altered once the equipment is built and installed. In contrast, the general-purpose computer's operation is dependent upon the program and the program is entirely dependent upon the ingenuity and knowledge of the programmer. The possibilities for this type of equipment are evident, not only in tank farm data handling and inventory control but in all of the operations of the associated production, transportation, and refining areas. The challenge is there; the ingenuity, we are sure, is also present; the future for this equipment, and the resulting savings appear to be most promising.

Economic Trends Make Railroad Electrification Inevitable

L. B. CURTIS
MEMBER AIEE

A survey of the economic and other factors that make electrification more desirable than the present diesel-electric system. An early revival of electrification in North America is predicted.

ELECTRIC OPERATION of railroads is the most economical form of motive power known today. There are many signs that point to an early revival of additional electrification in North America.

This article is intended to call the attention of the AIEE to at least 13 areas where electrification will effect economies over present diesel-electric operation and where the first cost of electrification will be reduced. The fact that there has been no new electrification in this country since 1938, rather there has indeed been some minor shrinkage, should not cause any thinking engineer to come to the erroneous conclusion that electrification is an obsolete form of transportation. In this country, existing major electrifications are still maintaining their record of dependability, flexibility, and economy, while abroad, electrification of railroads is growing by leaps and bounds.

The 26 engineers on Committee 13, Railway Electrification, of the Electrical Section of the Engineering and Mechanical Divisions of the Association of American Railroads (AAR) are virtually unanimous in their belief that many of the railroads will regard dieselization as a stepping stone to electrification of lines of heavy traffic density. This committee consists of electrical engineers representing 13 railroads, and consulting representatives from industry, including the Edison Electric Institute (EEI), manufacturers of electrical apparatus and materials, the telephone industry, the aluminum and copper industries, and consulting engineers.

The committee has three major objectives:

1. To keep the railroads up-to-date on electrification practices and statistics all over the world.
2. To recommend and develop for this country a standard system of electrification for through service on main-line tracks.
3. To keep alive and to encourage the faith of many engineers who believe that the future of railroad electrification in this country is bright.

In order to further these objectives, Committee 13 for several years has been co-operating with the International Union of Railways in Europe. Statistics and facts are also developed from around the world. The committee solicits the help of the AIEE and related electrical groups to aid it in its mission to demonstrate the economic advantages of electric operation, where feasible, over other types of motive power.

The basic reasons for the attention given by railroad management to railroad electrification are the measurable economic advantages. Management must be shown that electrification offers the most efficient and least expensive form of motive power for certain applications. It will then direct its attention to this field.

Railroad electrification offers many advantages over other modes of motive power which have a bearing on the over-all economics. Among them are the following:

1. Power generation in large centrally located plants is more efficient than in many small, space-limited units such as locomotives.
2. More traffic can be economically handled over the same number of tracks.
3. Electric locomotives have the highest availability and the least stand-by losses.
4. Electric operation is the cleanest and least noisy.
5. There is less terminal congestion.
6. Higher speeds are available for less cost.
7. Particularly at the higher horsepower ratings, the electric locomotive is the most compact in length.

THIRTEEN AREAS OF INFLUENCE

INASMUCH AS the economics of electrification compared with diesel-electric operation (now over 95% of all operation in the United States) is the major concern of this article, the 13 areas where electrification can and will produce savings and an improved financial condition for the railroads are now investigated:

1. The Signs Point to Conditions which Would Result in an Improved Load Factor

a. Largely as a result of competition from private automobiles, airplanes, trucks, and buses, there will be a trend toward more and more freight and passenger trains that are shorter, faster, and more frequent. This is already the situation abroad. In North America, freight and passenger trains have become longer in order to reduce costs, mainly labor costs. This has resulted

L. B. Curtis is with the Pennsylvania Railroad Company, Philadelphia, Pa.

The author wishes to express his appreciation to L. W. Birch, Ohio Brass Co.; H. F. Brown, R. Paul, and J. Stair, Jr., Gibbs & Hill, Inc.; C. J. Henry, J. W. Horine, and J. E. Hogan, Pennsylvania Railroad Co.; A. G. Oehler, Railway Locomotives and Cars; and to T. F. Perkinson, General Electric Co., for their helpful suggestions in the preparation of this paper.

in fewer trains; more costly yards, terminals, and stations; delays in delivery; and a mounting chorus of complaints on the part of the public. The railroads' competitors operate more frequent service in smaller units, and usually faster over-all. Railroads must meet this competition to get their fair share of the business.

b. The increased use of CTC (centralized traffic control) makes possible the operation of an increased number of trains on fewer tracks with the resultant abandonment of excess trackage.

c. The trend toward railroad mergers is increasing, particularly with railroads whose tracks parallel each other. With each merger will come abandonment of duplicating tracks and the consequent increase in the number of trains operating on remaining tracks.

As a result of these three factors, there will be more trains operating on remaining tracks and spread over the 24 hours of the day, thus producing a higher load factor at public utility generating stations with electric service. This type of load with its good diversity and high load factor is attractive as a base load to the power companies and would result in favorable rates for electricity.

2. Electric Locomotive Maintenance Cost Is Less than that for Diesel-Electric Locomotives or Any Other Type Motive Power Known

As diesel-electric locomotives become older, maintenance costs increase faster than maintenance on electric locomotives of the same age. Until railroads have been 100% dieselized for several years, diesel-electric maintenance costs will be misleading. The diesel-electrics have been acquired so rapidly between 1945 and 1955 that the average age has been kept low. The cost of maintenance of the new locomotives is averaged in with the older ones. This averaging of costs has hidden how fast the repair costs of the older units have risen. Now that most railroads are entirely dieselized, the rapid rise in maintenance costs will become apparent. In general, diesel-electric locomotives receive major overhauling in 3-year cycles, with this rhythmic cost curve rising until after about 15 years (compared to 25-30 years for the electric locomotive) the old locomotives have essentially been replaced or actually scrapped.

A recent paper[1] shows in graph form that "the general trends indicate that diesel-electric maintenance, reduced to the same common denominator, will be for locomotives 10 years of age at least twice the maintenance costs of electric locomotives."

Another paper[2] in discussing maintenance costs, over a period of 9 years, of electric locomotives on the Virginian Railway states, "The adjusted or constant-dollar cumulative cost to the end of 1956—23.2 cents per mile —represents a figure of 3.41 cents per 1,000 rated railhorsepower miles, a value approximately 1/4 to 1/3 of comparative diesel-electric locomotive maintenance costs for the same type of service performed."

The 25- to 30-year life of the electric locomotive is well substantiated. On the Pennsylvania Railroad, the 25-year-old *GG-1* locomotives are still giving successful service. The New York Central and the Chicago, Milwaukee, St. Paul & Pacific Railroads have still older electric locomotives in satisfactory service. On the Swiss Federal Railways, electric locomotives placed in service as early as 1920 are still in operation.

The lower cost of maintenance and the longer economic life of the electric locomotive compared to the diesel-electric spell substantial savings in favor of the former.

3. The Cost of Oil Is Expected To Rise Faster than the Cost of Electricity

One study[3] on the future cost of oil indicated, "By 1970 diesel-fuel costs are expected to increase by possibly 25 to 50%." Certainly, as the consumption of oil in this country and abroad increases, it will be necessary to search harder, drill deeper, and go farther to find additional oil reserves. As the reserves decrease, the need for synthetic oil increases. The net result is higher oil costs.

However, indications are that with increased efficiency, the cost of electric power will rise at a slower rate. W. H. Sammis, former president of the EEI, said significantly in 1954, and it is just as true today: "Our industry has established a unique record during this era of inflation when the purchasing power of the dollar had dropped 50%, when construction costs, federal taxes, labor rates, and the price of fuels have more than doubled. Through engineering achievements, improvements in operations, and well directed sales efforts, prices for electricity are lower today than they were before World War II. Where can you find another such example of accomplishment?"

At present, the cost of oil and electricity at the drawbar is, in general, approximately the same. As the differential between the cost of oil and electricity increases, the savings of electrification over diesel-electric operation increase.

4. The Use of Commercial-Frequency Power Will Reduce the Initial Costs of Electrification below those of the Older Established Systems

Recently, Committee 13 has recommended that the United States adopt the 25-kv 60-cycle system as its standard for main-line electrification. This system (50 cycles in most countries) is already in operation in the Belgian-Congo, England, France, Germany, Hungary, Japan, Luxembourg, Portugal, USSR, and Turkey. It is planned for Argentina and India. These foreign installations will be of great help to this country as the experiences abroad will help solve many of the problems that will confront American railroads in the event of 60-cycle electrification.

Among such problems are:

a. Load balancing on commercial 3-phase systems. A fine study[4] was made on this subject in this country by the American Gas & Electric Service Corp. on the Norfolk & Western Railway. The AIEE and the EEI can be of great service in furthering these studies, particularly

by encouraging young engineers to interest themselves in this and other railroad problems such as those mentioned throughout this article.

b. Inductive interference on communication and signal systems. Committee 13 with the help of the AT&T Company has made a comprehensive report on this subject. More work needs to be done.

c. Semiconductor rectifiers for locomotives. A good AIEE paper[5] was recently presented on the subject of semiconductor rectifiers for electric traction substations. Much more must be accomplished.

d. Improved pantographs.

e. Interpenetrating (intersystem) locomotives. In Europe, locomotives[6] have been developed that operate on four different systems; namely, 3,000 volts, d-c; 15 kv, 16⅔ cycles a-c; 25 kv, 50 cycles a-c; and 1,500 volts, d-c. The United States will need locomotives that will operate on at least two different systems.

The large increase in North America of high-voltage interconnecting lines which cross and recross the railroads makes the use of commercial-frequency electrification all the more feasible. This eliminates the necessity for railroad-owned transmission lines on railroad structures, as the contact system can be directly fed, with or without transformers, from these power lines. Co-operative studies would have to be made by the railroads and the power companies to insure a tolerably balanced load on the 3-phase lines with a minimum of disturbance to other loads fed from the same lines.

In addition to the elimination of the railroad-owned transmission lines, the 25-kv 60-cycle system would effect the following savings over existing types of electrification in this country:

a. At higher voltages, a lighter catenary system is possible.

b. With no transmission lines and lighter catenary, the structures and foundations will be smaller and lighter.

c. At higher voltages, substations can be installed farther apart.

d. Transformer stations can be wholly or partially eliminated, depending upon the commercial voltage available.

e. With higher voltage, the current will be lower, thus reducing the ampere rating of substation apparatus.

f. Frequency changers at supply points will be eliminated.

These savings are offset in part by the following additional costs of this system:

a. Somewhat greater clearances are required.

b. Increased insulation is necessary over some existing forms of electrification on overhead substation apparatus, and motive power.

c. There is the possible requirement of some load-balancing apparatus to maintain balance on commercial 3-phase systems where the latter are small and isolated.

d. Additional engineering will be required initially in developing this system.

5. Electrification Standards Will Reduce First Costs and Maintenance Costs

Standardization of electrification will reduce engineering, material, construction, and locomotive and multiple-unit car costs.

a. Engineering costs. With a standard pattern for extensions to existing electrifications and new ones, standardization will be possible for catenary systems, structures, substations, locomotives, etc. Basic engineering will have to be performed regarding catenary make-up, spans, pole and foundation sizes, and spacing and details of substations and sectionalizing points. For similar conditions of load, track curvature, and number of tracks to be electrified on any railroad, the same design will apply. Therefore, except for special problems, the engineering costs after the first study will be at a minimum.

b. Material costs. After the initial engineering has determined wire and pole sizes, hardware, apparatus sizes, and other standard parts, these same items can be used on any standard electrification interchangeably. With all railroads using the same type of material, quantity buying will reduce first costs, also the cost and amount of material to be stocked for maintenance. This should stimulate manufacturers to develop better and lower cost materials and apparatus.

c. Construction costs. With a standard specification, standard methods of construction will be developed, labor-saving devices employed, and packaged substations, such as the unit type, installed, all of which will reduce the cost of installation.

d. Locomotive and multiple-unit car costs. Nothing reduces first cost more than quantity production. In the past, electric locomotives have in general been custom made. When standard electric locomotives are accepted and used by all railroads, quantity production will greatly reduce both the first cost of motive power and maintenance costs. The same reasoning applies to multiple-unit cars.

Now that the North American railroads are almost completely dieselized, replacements will be purchased in reduced quantities with the accompanying loss in the economic advantages of high-volume mass production. Rebuilt diesels have not and undoubtedly will not show any advancement in technology. About all that can be expected are refinements in the present design which already has proven inadequate to provide an economic life comparable with the electric locomotive.

6. Conversion of Diesel-Electric to Electric Locomotives Will Save Investment Costs

The immense investment in diesel-electric locomotives can be conserved by electrification. Fortunately, those diesel-electrics that have not reached the end of their economic lives can be converted to electrics by replacing the diesel engines and the d-c generators with

rectifiers, or the diesel engines alone with a-c motors, plus necessary transformers and control. Thus, as has been predicted by other writers, the diesel-electric system would appear to be an intermediate step between steam operation and electrification.

7. Higher Speeds Favor Electrification

As mentioned under item 1, higher speeds for passenger and freight trains are sure to come in order to compete with the airplane, the trucks, and the buses. The higher the average speed of trains, the greater the financial advantage electrification has over any other type of motive power. In a recent study of a large section of an Eastern railroad, it was demonstrated that if speeds were increased an average of approximately 15% over present schedules, the annual savings of electrification vs. diesel-electric operation would triple. The following illustration demonstrates the advantage electric locomotives have over diesel-electrics at higher speeds.

The maximum train a locomotive can start depends upon weight on drivers and percent adhesion. At running speeds, there is the additional limitation of horsepower available. For both types of locomotives, reasonable figures are 25% adhesion in starting and about 16% at 60 miles per hour. At 60 miles per hour in the following illustration the limitation for each locomotive is horsepower, not the 16% adhesion.

A typical modern electric (rectifier) locomotive rated 4,000 hp (weight on drivers 174 tons) can start and accelerate on level tangent track a train of about 6,000 tons, and at 60 miles per hour can haul a 2,800-ton train continuously, or for a short time, due to its overload rating, can haul a 4,400-ton train at 60 miles per hour.

A typical modern diesel-electric unit locomotive rated 2,500 hp (weight on drivers also 174 tons) has approximately 82% or 2,050 hp available at the rails, as the 2,500-hp rating refers to the diesel-engine input to the main generator. This locomotive can also start a train of about 6,000 tons, but it can accelerate a train of only 1,200 tons to 60 miles per hour. The diesel-electric locomotive has no overload horsepower rating. As a matter of interest this locomotive can haul a 2,800-ton train at 38 miles per hour and a 4,400-ton train at 29 miles per hour.

On this basis it would take three (2.33) 2,500-hp diesel-electric units to haul a 2,800-ton train at 60 miles per hour and four (3.67) units to haul a 4,400-ton train at 60 miles per hour. In the first case, the electric locomotive would cost approximately $440,000 (based upon a relatively few custom-built units) and the diesel-electric locomotive approximately $810,000 (3 x 270,000) (based upon mass-production). In the second case, the electric locomotive would still cost $440,000 compared to a diesel-electric locomotive cost of $1.08 million (4 x 270,000).

Obviously, the more units of diesel-electrics that are necessary compared to the electrics, the higher in proportion will be the initial investment, the annual fixed charges, and the maintenance and operating costs for motive power.

It should be stated that the cost of the electrification fixed property—catenary, structures, and substations—would be substantially the same regardless of the speed.

8. CTC Will Reduce Number of Tracks To Be Electrified

Inasmuch as the installation of centralized traffic control permits more trains to be operated on the same track, the resultant number of tracks to be electrified is minimized, thus reducing the number of tracks required to remain in service by at least one, and in some multitrack areas by two or more. In many cases, 1-pole bracket structures can be used instead of 2-pole structures, the number of miles of catenary required is lessened, and the sectionalizing and substation requirements are reduced. This situation, brought about by the increasing use of CTC, will reduce the first cost and later the maintenance cost of electrification.

9. Joint Use of Right-of-Way Possible with Electrification

As areas are being built up and cities and suburbs are expanding, utilities, particularly the power companies, are finding it more and more difficult and expensive to find right-of-way for their transmission lines. In many areas they are looking to the railroads for joint use of their right-of-way. This is an ideal arrangement for the power companies as the railroad right-of-way is already cleared and protected. Hence, a natural procedure would be for the utilities to erect structures that are suitable for attaching electrification wires if and when the railroad is electrified. Provision for just such an arrangement has already been included in some existing agreements. Since the rentals to the utilities take into account future electrification, such a joint use of the structure is of mutual benefit and would result in a considerable reduction in the cost of the fixed portion of the electrification to the railroad.

10. Electrification Permits Additional Income from Air Rights

In congested areas, one of the valuable assets a railroad has is its air rights. Previously with steam, and now somewhat less with diesel-electric locomotives, these valuable air rights in heavily populated areas, could not be used since ventilation is essential. With electrification, areas of air rights can be sold or rented, bringing to the railroads additional needed revenues. The value of this product of electrification should not be overlooked.

11. Future Use of Atomic Power

Vice-Admiral Rickover had this to say[7]: "Another limit in the use of nuclear power is that we do not know how to employ it otherwise than in large units to produce electricity or to supply heating. Because of its inherent characteristics, nuclear fuel cannot be used directly in small machines, such as cars, trucks, or tractors. Rather than nuclear locomotives, it might prove

advantageous to move trains by electricity produced in nuclear central stations."

During August of 1959, the writer had the privilege of inspecting the new Dresden Nuclear Power Station which is scheduled to go in service early in 1960. This plant will add 180,000 kw to the Commonwealth Edison Company of Illinois' reservoir of electricity. It is estimated that by 1975 the United States will be using nearly four times as much electricity as today—a tremendous drain on the reserves of coal, oil, and gas. Hence, atomic power must be used to help meet future electricity needs. It is expected that after the high initial development costs are absorbed, the cost of generating electricity by atomic power will compete with that using conventional fuels. With the experience gained from this large experimental plant, other more efficient atomic power plants are already in the building and planning stage.

Thus, atomic power will do its part in producing abundant amounts of electricity at reasonable costs to take ample care of the future needs of electrification.

12. Possible Shortage of Oil Due to War, etc. Makes Electrification Desirable

In the event of war or some other catastrophe that would bring about a shortage of oil, rationing, and priorities, the railroads, with all their motive power dependent upon oil, could very well be in trouble. It would be a decided advantage for rail transportation, under such conditions, to have its major lines electrified, for the generation of electricity is not dependent upon oil alone. Other fuels and sources of power such as water, coal, poorer grades of oil, gas, and atomic power would give a diversity that could keep the railroad wheels turning.

13. The Effect of the Foreign Market on Electrification

Another item that will undoubtedly reduce the cost of electrification in this country is the competition of the foreign market. Unfortunately for our home suppliers of material, apparatus, and equipment, our high cost of labor is driving prices up to the point where foreign goods are being sold in this country in increasing amounts. Unless something is done, this situation will worsen rather than get better. In that event we might look forward to electrification in the United States being constructed almost entirely with foreign material and apparatus, and trains pulled by foreign-manufactured locomotives. At any rate, the foreign competition will tend to lessen the cost of future electrification. Of course, foreign competition will tend to lower the cost of diesel-electric locomotives too, but anything that will help reduce the first costs will make electrification more attractive.

SUMMARY

To SUMMARIZE, the following factors point to the ultimate reduction in cost of electrification facilities and reduction in the cost of operation of railroads with electrification to the point where electrification must be considered:

(1) A high electric load factor; (2) Reduced locomotive maintenance with electric locomotives; (3) Favorable cost of electricity vs. oil; (4) Use of commercial-frequency electricity for electrification; (5) Standardization of electrification; (6) Conversion of diesel-electrics to electric locomotives; (7) Higher speeds; (8) Number of tracks reduced by CTC; (9) Joint use of right-of-way; (10) Increased sale of air rights; (11) Use of atomic power; (12) Shortage of oil in times of national emergencies; and (13) Effect of the foreign market.

CONCLUSIONS

IT IS THE FIRM OPINION of the writer that these factors will not only produce a form of motive power that is more economical to operate and maintain than the present diesel-electric system, but will reduce first costs of electrification to a point where they are equal to or below the cost of the additional diesel-electric motive power required to give equivalent electric service.

The evidence presented points to a more and more favorable economic position of electrification compared with other forms of motive power. This is of prime importance to the railroads themselves as they are forced to compete under the present unfair conditions of subsidy, taxation, and antequated regulations. It is of national importance that the railroads be strong and efficient—in times of national emergency no other mode of transportation in existence can replace them. Electrification is also of importance to the power companies, the electrical manufacturers, and other related industries. It will contribute immensely to the nation's prosperity. It is a project worthy of the best efforts of the AAR, AIEE, EEI, NEMA (National Electrical Manufacturers Association), etc. With sufficient united effort and unanimity of opinion on the part of the engineers, railroad management will be glad to "Stop—Look—Listen." Their investigations will convince them that electric motive power will give them the most efficient and economical operation obtainable—and then the resurgence of railroad electrification will be inevitable.

REFERENCES

1. A Reappraisal of the Economics of Railway Electrification: How, When, and Where Can It Compete with the Diesel-Electric Locomotive?, H. F. Brown, R. L. Kimball. AIEE *Transactions*, pt. II (*Power Apparatus and Systems*), vol. 73, March 1954, pp. 35-45.

2. Virginian Railway Motor-Generator Electric Locomotive Maintenance Costs, T. F. Perkinson. AIEE Conference Paper CP57-728.

3. A Preliminary Investigation of the Possibilities of Expansion of Railroad Electrification in the United States Battelle Memorial Institute, Columbus, Ohio, April 23, 1952, p. 2.

4. Technical Aspects of Providing Service to Single-Phase, 60-Cycle Railroad Loads. T. J. Nagel, A. F. Gabrielle. AIEE *Transactions*, pt. II, (*Power Apparatus and Systems*), vol. 77, July 1958, pp. 172-76.

5. Semiconductor Rectifiers for Traction Power on Electric Railways. V. E. Staff, S. B. Lent. AIEE Conference Paper CP59-799.

6. Four-System Electric T.E.E. Trains, *Railway Gazette*, London, England, April 10, 1959, p. 419.

7. Remarks prepared by Vice-Admiral H. G. Rickover, USN, Chief Naval Reactors Branch, Division of Reactor Development, U. S. Atomic Energy Commission. Annual Scientific Assembly of the Minnesota State Medical Association, St. Paul, Minn., May 14, 1957.

Stability Criteria for Instrument Servomechanisms

M. P. PASTEL

G. J. THALER
MEMBER AIEE

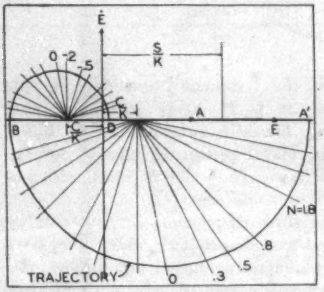


Fig. 1. Phase trajectory of a second order servo with coulomb friction and stiction.

ALL RUBBING SURFACES are subject to friction in three forms: the usual viscous friction; coulomb friction which is a reaction force independent of velocity; and stiction, the phenomenon that surfaces at rest stick together and require a greater force to initiate motion than is required to maintain motion.

When present in feedback control systems, coulomb friction and stiction cause static inaccuracies, increased velocity lag errors, and jumpy action at low velocities. By using the isocline method, the effects of coulomb friction and stiction on the step response and the ramp response become quite evident. The jumpy action commonly encountered at low velocities appears on the phase plane as a limit cycle, and stability criteria may be derived to predict the conditions for its existence.

For a second order system, the differential equation in terms of error, E, is

$$J\ddot{E} + f\dot{E} + KE + C \text{ sign } \dot{E} = 0$$

from which the isocline equation is

$$\dot{E} = \frac{-KE - C \text{ sign } E}{NJ + f}$$

where

C = coulomb friction
f = viscous friction
J = polar moment of inertia
K = torque constant
N = slope of phase trajectory

Fig. 1 shows the isoclines and a phase trajectory. The effect of the coulomb friction is twofold: it provides for two foci, and defines the E-axis as a dividing line which designates the focus to be used. When a trajectory reaches the E-axis between foci, motion terminates.

Applying the isocline procedure to the case of a ramp input, additional effects due to the input velocity are a translation of the $\dot{E}$-axis with respect to the foci, and a translation of the dividing line from $\dot{E} = 0$ to $E = \omega_i$, the input velocity. When the ramp is applied, the output sticks until the error builds up such that the drive torque, KE, equals the static friction torque, at which point motion begins. For coulomb friction only, the break-free point on the phase plane is the intersection of the dividing line with the $N = 0$ isocline, from which it follows that the phase trajectory can never again reach the dividing line (if $\zeta > 0$) and the system is stable. For the case of stiction plus coulomb friction, the break-free point is determined by the stiction, and the phase trajectory thus designated can (for sufficiently low input velocity) reach the dividing line; the output then sticks and a limit cycle is established. The phase trajectories may be described by linear equations, and application of boundary conditions permits derivation of a stability criteria to predict the existence of a limit cycle in response to a suddenly applied ramp input. A plot of this stability criteria is shown in Fig. 2.

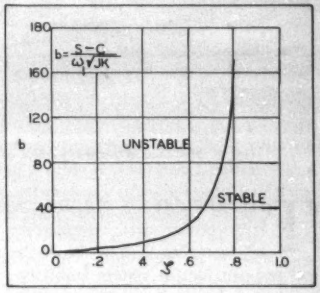


Fig. 2. Graph of stability criterion for second order servos with stiction, ramp input.

Fig. 2 indicates that any system is stable if the input velocity is high enough. Thus, it is possible to start a system at high velocity and let it reach steady state without limit cycle. Once this is done the input velocity may be lowered in steps, providing that for each step the final input velocity, ω_2, is related to the initial input velocity in such a way that

$$\omega_2 > \frac{\omega_o}{1 + e^{\pi\zeta}}$$

Digest of paper 59-649, "Stability Criteria for Instrument Servomechanisms with Coulomb Friction and Stiction," recommended by the AIEE Feedback Control Systems Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., May 19-21, 1959. Published in AIEE *Transactions*, pt. II (*Applications and Industry*), vol. 78, Nov. 1959, pp. 294-97.

M. P. Pastel and G. J. Thaler are with the U. S. Naval Postgraduate School, Monterey, Calif

Telemetering Applications and Operation on a Large Power System

D. E. JOHANNSON
ASSOCIATE MEMBER AIEE

In large power systems, it is essential that load dispatchers have before them at all times a graphic picture of the many variable quantities they are supervising. The various types of continuous telemetering equipment in use on the Bonneville Power Administration's transmission system are described.

Fig. 1. BPA load dispatcher's office at Portland, Oreg.

THE EFFICIENT OPERATION and control of a large power system requires a reliable high-speed telemetering system. Power system load dispatchers responsible for system stability and for maintaining customer service, as well as the interchange of power at tie points with other areas, must have before them a continuous graphic picture of the variable quantities they are supervising. The several types of continuous telemetering equipment applied to and operated on the Bonneville Power Administration (BPA) transmission system will be discussed.

The transmission of power from all of the Federal hydroelectric plants in the Columbia Basin is the responsibility of the dispatching and operating personnel of the BPA. The system is divided into three operating areas with dispatching of all power at voltages of 230 kv and higher from the load dispatcher's office in Portland, Oreg. Secondary transmission at the 115-kv level for certain portions of the system is controlled by subdispatchers located at J. P. Alvey substation near Eugene, Oreg., and Franklin substation near Pasco, Wash. In addition, major operating stations for the Seattle and Spokane areas are located at Snohomish and G. H. Bell substations, respectively.

There are two or three dispatchers continuously on duty in the Portland load dispatcher's office. They have displayed on a semi-encircling board a complete one-line diagram of the power system, together with approximately 80 strip chart recorders representing 60% of the system's telemetering circuits, as illustrated in Fig. 1. The Portland installation provides the dispatchers with continuous indication and recording of the following quantities:

1. Generation for nine Federal hydroelectric projects.
2. Total load on each of 19 major power lines feeding the load centers.
3. Total load into each of the three operating areas.
4. System frequency from each area.
5. The net power interchange with each of 10 interconnected utilities and many of the major individual interchanges with these utilities.
6. Selective telemetering from each area, providing indication of any individual quantity which is normally retransmitted to Portland as part of a total.
7. Net generation, hydro and steam, of many of the interconnected utilities forming the Northwest power pool.

With these data, the dispatchers have constantly before them the facts they need to meet the demands made on the system. They can divide loads among lines and stations for maximum operating efficiency and can maintain scheduled generation to meet the tie-line interchanges. Because of the complexity of the BPA system, dispatching is decentralized to some extent at the various subdispatcher's offices and major area substations.

The remaining 40% of the telemetering system serves these secondary operating points. The objective of this portion of the telemetering system is to bring into each central area station all of the local power interchanges, in order to facilitate operations in that area. The individual quantities are recorded and then totalized into net interchange recorders for each interconnected utility. The net interchanges are retransmitted to the Portland dispatcher's office where they form a part of the net power pool interchange. A separate telemetering channel from each secondary operating point permits retransmission of any individual quantity to Portland,

Full text of paper 60-242, presented at the AIEE Winter General Meeting, New York, N.Y., Jan. 31–Feb. 5, 1960. Recommended for publication by the AIEE Power System Communications Committee. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1960.

D. E. Johannson is with the U. S. Department of the Interior, Bonneville Power Administration, Portland, Oreg.

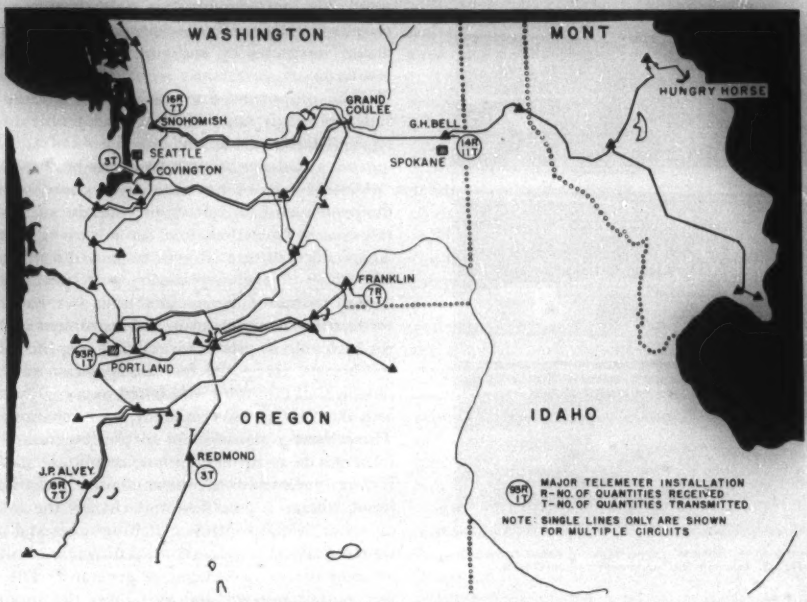


Fig. 2. Main BPA transmission grid, indicating major telemetering installations.

if required during a critical period. The scope of the power system and a summation of the number of telemetered quantities handled at the main points on the system are illustrated in Fig. 2.

This dispatching network provides for maximum flexibility of system operations and limits the burden on the Portland dispatchers. The requirement for long telemetering circuits is minimized, since only the quantities of primary importance are brought the full distance into Portland.

TYPES OF EQUIPMENT IN SERVICE

Prior to 1950, because of the lack of economical communication circuits, telemetering on the BPA system was limited to major generation and the interconnecting tie lines readily available over leased-line and power-line carrier. Since that time, the installation of multichannel microwave between all major BPA substations and Federal hydroelectric plants in Washington and Oregon has enabled an orderly expansion of the telemetering system proportionate to power system growth.

The first telemetering equipment employed was of the slow-speed impulse type. Most of the circuits using this type equipment are co-ordinated with the telemetering of interconnected utilities and are still in service. When it became feasible to provide system-wide telemetering economically, the first basic requirement was that the equipment provide high-speed response to system disturbances. Specifications for the first major installations were based on extensive performance tests on actual equipment through the co-operation of the major equipment manufacturers. This initial order for high-speed telemetering equipment was for a type of equipment employing a subaudio varying-frequency signal. Since then, two other types of high-speed variable-frequency equipment have been installed.

The basic operation and characteristics of the three types of frequency telemetering now in service are similar in many respects. The primary distinction is in the range of frequency shift corresponding to a change in the measured quantity from zero to full scale. The Type A equipment has a range of 20 to 25 cps (cycles per second), Type B has a range of 6 to 27 cps and Type C has a range of 10 to 30 cps. In all of the Type A and C and a few of the Type B equipments in use the transmitter output frequency is generated and controlled electronically, with the variation in frequency proportional to the output of a thermal-converter metering device. The majority of the Type B equipment employs the rotating disk of a watt-hour meter movement for frequency generation and control.

The receivers for each type of equipment utilize various schemes for rectifying the varying frequency, to provide a d-c output directly proportional to the metering watts at the input to the remote transmitter. It is interesting to note that the three types have a degree of accuracy and speed of response very closely comparable. Fig. 3 illustrates over-all response of each type.

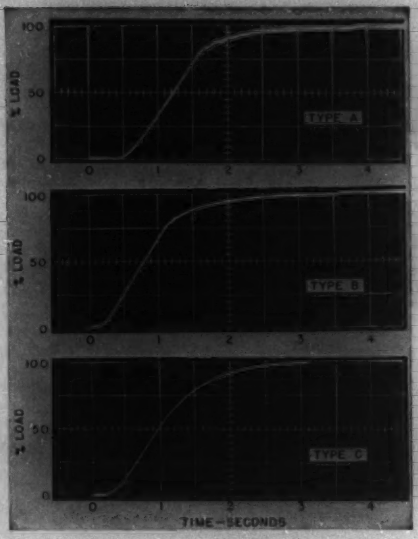


Fig. 3. Telemetering equipment response tests.

The response tests were conducted by applying a 100% load change to the metering device and recording with an oscilloscope the output of a recorder slidewire driven from the telemeter receiver. The slight improvement in response of the Type B over the other two apparently results from the metering equipment. The watt-hour meter movement is an integral part of the Type B transmitting equipment, whereas a separate thermal metering device drives the Type A and C transmitters. In addition, the Type A equipment has a potentiometer recorder between the thermal converter and the transmitting oscillator.

MEGAWATT-HOUR INTEGRATORS

In the daily operation of the power system, checking schedules of power interchange at many points of interconnection is facilitated by hourly readings of total energy exchanged during the schedule period. Since maintaining schedules must be a continuous process, the majority of these readings are obtained directly by telephone from the megawatt-hour billing meters at the substations.

In order to reduce the man-hour requirements and obtain the hourly readings directly from existing telemetering, a program was instigated several years ago to encourage development in the industry of a megawatt-hour integrator. The objective was a device which would operate from the received telemeter signal of a continuous power rate, integrate the quantity with respect to time, and provide a digital output of the accumulated megawatt-hours. One manufacturer has had a mechanical integrator on the market for many years. The unit mounts in a strip chart recorder and couples directly to the slidewire or balancing shaft. The device integrates by engaging a counter, once every revolution of a constantly rotating ratchet, for a period of time proportional to the angular position of the slidewire. It is not universally adaptable to various types of telemetering, and has the disadvantage of requiring a recorder on each circuit to be integrated.

Another type of mechanical integrator operates on the principle of converting the impulse of an impulse-rate-type telemeter channel to a varying rpm value. This is then integrated with respect to a constant rpm rate (time) through a planetary gear system to drive a digital counter. The manufacturer has had difficulty with various components in the instrument and has not yet been able to produce a reliable long-life integrator.

The type integrator now in operation on the BPA system is all electronic and based on a highly stable d-c amplifier and an integrating capacitor charging circuit. The telemeter signal input to the integrator is in the form of a d-c millivoltage whose amplitude and polarity is directly related to the instantaneous power flow. This input voltage is amplified and charges the integrating capacitor, which controls switching tubes and mercury-wetted relays. The relays control direction of rotation of a motor driving a tachometer generator. The tachometer output opposes and overcomes the input signal, discharging the capacitor and stopping the motor. This integrating function and feedback keep recycling. The voltage–time integral of the tachometer output corresponds exactly to the number of shaft rotations. Therefore, by coupling two mechanical counters through unidirectional slip clutches to the shaft, the instrument can be calibrated to read out total energy in megawatt-hours in both directions on a 2-way metering circuit. On repeated tests at low level inputs for a fixed period of time, the integrator error has been of the order of 0.1%. The main problem has been to reduce errors in telemetering circuits, since the integrator error is so small that it is insignificant.

There are approximately 25 integrators of this type operating on the BPA system, with very satisfactory results. It has been adapted quite easily to the various types of telemetering. The Type A telemetering equipment requires a recorder slidewire for driving the integrator. The Type B and C telemeter receivers have multiple output and can be calibrated for direct connection to the integrator. In the case of impulse receivers, which provide only 1 millivolt output, a receiver circuit modification was developed to permit two outputs of different calibration.

ICE-LOAD TELEMETERING

One telemetering project on the BPA system is relatively new. It is the development and installation of equipment to measure and telemeter the tensile load caused by the formation of ice on a power-line conductor. There is now in operation an ice-load telemetering station in the Cascade Mountains near Stevens Pass,

east of Snohomish, Wash. Two 230-kv lines and two 345-kv lines cross the mountains through this pass. The dead-end load of the center phase of one of the 230-kv lines is measured with a strain-gage-type load cell in the insulator string. This controls a telemeter transmitter located in a nearby patrol shelter. The signal is transmitted via power-line carrier to the Snohomish substation where it is continuously recorded with provision for retransmission to the Portland load dispatcher's office. In addition, signals from an ice detector are superimposed on the continuous load reading to serve as advance warning of icing conditions and also give some indication of how fast the ice is forming.

Power to operate the telemetering and carrier equipment is obtained from the 230-kv transmission line by use of a special potential device in the carrier coupling capacitor. If a power-line outage occurs, the equipment transfers automatically to a nickel–cadmium storage battery to permit emergency operation for at least 8 hours. Tentative plans call for the addition of ice-load metering on the other three lines in this pass and construction of additional stations near other lines where critical icing occurs.

COMMUNICATION CHANNELS

THE TELEMETERING EQUIPMENTS described are utilized on the BPA system over a variety of communication channels, the majority of which are tone-submultiplexed microwave channels. At the load dispatcher's office in Portland, there are eight voice-band microwave channels devoted almost entirely to continuous high-speed telemetering. The individual voice channels are divided into narrow-band frequency-shift tone channels to accommodate up to 16 telemeter quantities. Five of the microwave channels are long-haul circuits and are loaded nearly to capacity. The remaining three now in use are short-distance circuits, loaded lightly and, in some cases, shared with other services such as supervisory control and digital telemetering.

A considerable number of frequency-shift power-line carrier circuits are in use to telemeter quantities from remotely located substations. The majority of the slow-speed impulse-rate telemetering is over 0-to-15 cps grade leased telephone lines. In addition, a few point-to-point radio circuits in the vhf and uhf bands are employed where other type circuits were not practical.

Some of the problems related to tone-submultiplexed microwave may be of interest. Frequently, momentary disturbances occur on the microwave systems due to switching transients, noise bursts, occasional fades, and loss of pulse synchronization. Because of their effects on telemeter recorders and other services on the microwave system, it has been necessary to take certain precautions in the installation design of tone-submultiplex equipment. The high-speed response of telemeter recorders causes them to attempt to follow any momentary disturbance. During noisy periods, the result is constant painting of the recorder chart and increase in wear on the balancing motor and pen-drive mechanism. To correct this, noise-squelch tone receivers have been installed, one on each microwave channel used for telemetering.

The squelch receiver compares channel noise with one of the tones on the channel. The object is to control all of the chart recorders operated from that microwave channel if the signal-to-noise ratio on one tone drops to a predetermined value. It is generally true that if noise occurs it will be distributed over the entire voice-channel bandwidth. The output relay of the squelch receiver operates before the disturbance gets through the tone receivers. By means of a delay relay and multiple-pole relays, the balance motor circuits in all the recorders on the noisy channel are opened, stopping the pen and preventing a reaction to the disturbance. When the channel clears up, the squelch relay resets, but reclosing the balance-motor circuits is delayed approximately 5 seconds. This delay allows the telemeter receiver output to recover to normal output after restoration of the input signal. A pilot light on the face of the recorder is lit when the recorder is squelched. The system has proven very satisfactory, and normally squelch operations cannot be detected on the chart recording unless the squelch or outage lasts 5 minutes or longer. An extended outage will be indicated by a straight line drawn at the last telemeter reading. Fig. 4 shows the improvement in telemeter recordings obtainable by squelch control during a noisy microwave period.

The second problem regarding tone-submultiplexed microwave is the danger of causing false operations in critical services in use on other voice channels when momentary loss of channel synchronization occurs. Upon loss of channel synchronization, the output of any given channel demodulator will have the modulation of each channel appear at its terminals in rapid succession as the channels slip by. High-speed frequency-shift tone equipment is being used on the microwave system for automatic power-line relaying. It would be very undesirable to have a channel output loaded with telemeter tones suddenly appear at the input to a tone receiver whose output relay contacts are in the trip circuit of a 230-kv circuit breaker. To guard against this possibility of a false trip, the tones for telemetering are grouped and assigned at each point of insertion into the microwave system in such a way that they will

Fig. 4. Effect of channel disturbances on high-speed telemetering is indicated on left recorder. Recorder on right is operating with noise-squelch protection.

always produce a "trip block" if accidentally applied to a microwave relaying terminal equipment.

The microwave relaying tone receivers are biased toward the "space" side of the frequency shift and will not operate if tones simultaneously appear on both the "space" and "mark" sides. Therefore, telemeter tone channels which fall within the "mark" side of a relaying channel are not inserted into the microwave unless accompanied by tones falling on the "space" side of the same relaying channel.

The use of telephone lines, in particular the 0–15 grade channel, is limited to direct current and low-speed impulse-rate telemetering circuits on the BPA system. In several installations, the millivolt output of a thermal converter is carried over many miles of line without difficulty, provided that a good-quality low-noise circuit is available. For impulse-rate telemetering a multiplexing scheme is frequently employed to transmit two impulse circuits over a single 0–15 grade channel, thus halving the channel cost. The method is mostly applicable to short circuits. Two telephone-type relays are keyed over one line by use of a 60-cycle source and polarizing selenium rectifiers to operate one relay on positive half cycles and the other on negative half cycles.

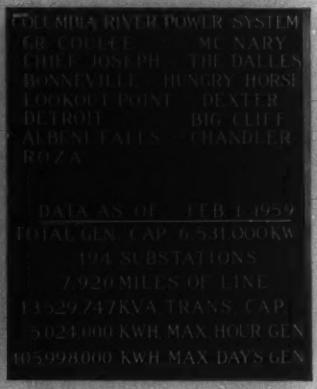


Fig. 5. Columbia River Power System data.

CONCLUSION

This discussion has been devoted primarily to continuous telemetering applications on the BPA system. A brief description of the operating and dispatching organization has been included together with the basic design of the telemetering system in service. As a further aid to the operating personnel on the BPA system, there are several installations of intermittent point selection telemetering. This equipment is installed as an accessory to supervisory control of unattended substations and is primary slow-speed impulse-type equipment. In addition, there is one circuit of automatic digital telemetering which hourly tabulates, on teletypewriter machines, all meter readings from a remote substation.

Telemetering of river-gauge readings from all the Federal dam reservoirs also is accomplished on an automatic intermittent system. This system, using a pulse-counting scheme, provides reservoir elevations to the nearest hundredth of a foot. River-gauge telemetering furnishes the basic data for allocation of generation among the hydroelectric plants for optimum water use.

Advance planning has been essentially completed for the addition in the near future of centralized automatic load-frequency control equipment. This will provide automatic control of the major federal hydroelectric plants on the Columbia River. Telemetering of system loads, generation, and generation control with the highest speed, accuracy, and reliability will become of prime importance. Most of the circuits required for the initial load-frequency control installation are in operation except for outgoing plant generation control. Other additions to the BPA system will be determined by growth of the transmission system and continued refinements in the operation dispatching, and automatic control requirements.

Lamp Annunciators

Edwards Company (Norwalk, Conn.) new industrial lamp annunciators are shown in a typical utility installation. Mounted above the control panels, the new units are used to monitor temperature and pressure changes, opening and closing of circuits, and high- and low-liquid levels in complex generating equipment and switchgear.

The new units are flexible and modular. Some of the outstanding features of the Edwards systems are: plug-in circuits which can be removed easily and changed for different operational sequences, multiple lamps to insure a signal even in the event of lamp burn-out, quick change "snap-in" indicator plates, sequential circuits, data-logging terminals, and snap-fit 1-piece molded lamp compartments that can be removed without any tools.

5005 Aluminum Alloy Cables for Overhead Lines

H. W. ADAMS
MEMBER AIEE

THE WIDESPREAD ADOPTION of aluminum conductors for urban overhead power systems during the last 10 years has created a demand for a homogeneous aluminum-alloy cable having better sag characteristics than one made of EC (electrical grade) aluminum. With *5005* aluminum alloy, cables have been developed which meet this demand. In addition, since *5005* is a nonheat-treatable alloy, wires can be produced on conventional equipment and manufacturing costs are low.

Used for wrought products other than wire for many years, *5005* is a standard commercial alloy. Its nominal composition is 0.8% magnesium, the remainder being aluminum and impurities. Properties of *5005* wires in the hard-drawn temper are as follows:

Tensile Strength. The average tensile strength ranges from 32,000 to 37,500 psi (pounds per square inch), compared to 24,000 to 28,000 psi for EC aluminum.

Elongation. The minimum elongation in 10 inches ranges from 1.4 to 2.0%, which is the same as for EC.

Conductivity. The minimum conductivity of *5005* wires is 53.5%, which provides conductance in a 7-strand cable somewhat greater than in a 6/1 ACSR (steel reinforced aluminum cable) the same physical size.

Modulus. The virtual initial modulus of *5005* cables is 7.3×10^6 psi, and the final modulus is 9.1×10^6 psi.

Hardness. The Rockwell 15T hardness number is about 71, while that for EC is about 55.

Fatigue. The ratio of fatigue endurance limit to tensile strength of *5005* wires is equal to or greater than the ratio for EC wires. Cables made of *5005* alloy can be expected, therefore, to withstand the effects of vibration at least as well as EC cables.

Notch Fatigue Sensitivity. In the same actual service, *5005* and EC wires would be exposed to the same forces which might cause nicks or scratches, and the 5005, being harder, would be nicked or scratched to a lesser degree. Since the ratio of fatigue endurance limit to breaking strength for *5005* wires is equal to or better than the ratio for EC, they should be at least no more subject to damage from notch fatigue than EC.

Effect of Elevated Temperature. The loss of tensile strength of *5005* and EC wires after prolonged heating at temperatures of 90, 100, and 140 C is approximately the same, in terms of percentages of ultimate strength.

Resistance to Corrosion. Since magnesium, the alloying constituent for *5005*, has a place slightly above EC in the galvanic series, *5005* would be expected to be at least as resistant to corrosion as EC.

Creep Characteristics. The total nonelastic stretch in *5005* cables is almost exactly the same as that for EC cable after both have been held for a period of time at stresses representing the same percentages of their ultimate strengths.

The electrical characteristics of 7-strand *5005* cables, of the same physical sizes of 6/1 and 26/7 ACSR, compare closely. The current-carrying capacities of *5005* cables are greater than those of approximately equivalent EC, copper, or ACSR cables because of differences in physical size and the magnetic losses in the steel core wire.

The tensile strength of *5005* cables having approximately equal d-c resistance to conventional EC, ACSR, and copper cables is somewhat greater than that of the comparable copper cables, and is about midway between the strengths of EC and 6/1 or 26/7 ACSR. For the same physical size, it is slightly higher than for 18/1 ACSR.

In evaluating different types of conductors, it is important to consider their sag and tension characteristics. There sometimes is a tendency to relate tensile strength directly to sag and tension behavior, but this can be misleading. In addition to strength, this behavior is influenced by other properties of the cables such as modulus of elasticity, temperature coefficients of expansion, fatigue endurance limit, creep, weight, and physical size. Further, it is strongly influenced by the line design parameters such as weather conditions to be designed for, normal span lengths, strength of supporting structures, permissible sags, etc.

The only completely satisfactory way to compare the sag and tension behavior of conductors of different sizes and types is with data calculated for each under the same design conditions. In such comparisons for relatively short spans, *5005* cables show less sag than EC in all instances and approximately the same sag as ACSR in many. In addition, sags of *5005* compare quite favorably with those for copper.

Homogeneous cables of *5005* aluminum alloy are especially attractive for lines having span lengths in the range normally encountered in urban areas. They are also extremely attractive for use as the bare neutral messenger for self-supporting secondary and service drop cables. In such cables, they afford an economical means of providing extra strength without introducing any inconvenience or problem relating to a steel core wire.

Since the beginning of 1958, substantial quantities of *5005* cables have been installed in widespread locations throughout the United States. Installation experiences have been excellent in every respect.

Digest of paper 59-868, "Design of Overhead Lines with 5005 Aluminum Alloy Cables," recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer and Pacific General Meeting and Transportation Conference, Seattle, Wash., June 21-26, 1959. Published in AIEE *Power Apparatus and Systems*, Dec. 1959, pp. 1290-1300.

H. W. Adams is with the Reynolds Metals Company, Richmond, Va.

An Electrical Essay
The Gravy Train

THE T&D RR,* together with its Gravy Train, was invented during the Thanksgiving holidays. This revolutionary new power source and form of transport is revealed here for the first time.

A very long iron pipe is shown in Fig. 1(a), with cross ties and rails installed inside. The locomotor rides the rails, and is geared to them. This is a cogwheel railroad. The permanent magnet *NS* is geared through the wheels to the track, by way of its shaft and a suitable mechanism. If the locomotor is pushed along the track, the magnet rotates.

With this much of the system built, we get some little men to ride the pole faces, armed with spray guns. Their function is to stripe the walls. The gearing is such that the stripes will be long, gentle spirals.

The wiring comes next, with the wires laid along the stripes. Where the spiralled wires cross the bottom, they are allowed to pass through the rail bed. When the wires are connected in series at each end, with a battery in the circuit, the currents will be as shown. Thus constructed, it is seen that no matter where the locomotor may be along the track, the poles are always facing their bands of conductors. The Gravy Train consists of the locomotor and any number of cars.

We install the locomotor at our end of the pipe and turn on the current. A clockwise torque is produced, ready to turn the magnet on its shaft, and through the gearing, propel the locomotor away from us.

Get one of the little men to ride a pole again (on overtime, if need be). He points his right index finger at the gap between two spiralled wires. As he whirls along, his finger always points between those two wires. If the finger is really a line of the magnet's flux, the flux glides along the wires, and never passes across them.

The remarkable advantage of this new motor now is clear: no back emf is induced. The only power input required is the I^2R in the conductors. This is small, and constant; whereas, the motor develops constant torque, and the faster it goes the greater would be the power developed. If this is not a Gravy Train, what would be?

Two improvements readily come to mind, especially during a holiday. Both are shown in Fig. 1(b).

First, we make the system endless, by cutting off several full spiral pitches of the pipe, bending it into hollow doughnut form, and joining the ends. The Gravy Train now circulates endlessly.

Second, why tolerate any input, even I^2R? Make the pipe of clear plastic instead of iron. Order a lot of Alnico *C*-magnets with flat sides. One of these is shown in place, at the right. Omit wires. This magnet would produce a torque, at this position. Now place the *C*-magnets side by side, all the way around the system; but give them slight angular shifts from one to the next, so that the poles make the same kind of a spiral the wires had. Anywhere the Gravy Train happens to be, the torque would be there to drive it. There is plenty of output, and no input. The output goes to drive the train through its friction and windage.

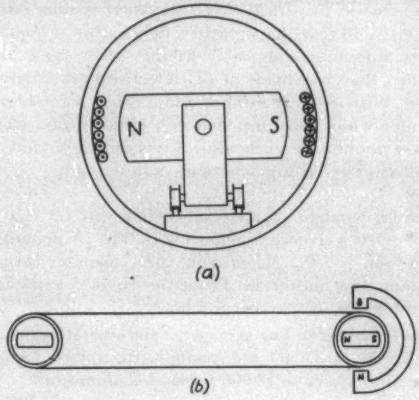


Fig. 1.

By evacuating the pipe and reducing friction to near zero, we have here the GTPA, or Gravy Train Particle Accelerator. Put the protons in car no. 1, turn the train loose, and let it accelerate to near the velocity of light. This calls for banking the track to about 90 degrees.

To limit the speed and particle energy to any desired value, some form of negative feedback would be applied. (Feedback had to get into the manuscript, for no paper gets by nowadays unless the word appears at least once.)

Those spoilsports at the United States Patent Office, when presented with an advance of this sort, automatically reject it with, "You cannot have perpetual motion." Let us ignore them. We don't want their old patent anyway. Aside from that, there may be some killjoys running at large, anxious to wipe out such a thing as the Gravy Train with the same remark. Let them pause: instead of giving the airy dismissal and passing to other things, why not show *specifically* why the Gravy Train may not even pull away from the station? Moreover, when and if that is shown, there is one more question: will there be any stresses in the gear mechanism?

A. D. MOORE (F '43)
(University of Michigan, Ann Arbor, Mich.)

* T&D RR: Turkey and Dressing Rail Road

Convergence of Iterative Load-Flow Studies

J. E. VAN NESS
MEMBER AIEE

A THEORY has been developed for explaining the convergence of iteration methods used in the solution of power flow problems in large electric networks. This theory will predict the improvement to be expected when using certain acceleration techniques, thus giving a means for determining the fastest convergence for a given problem. The new understanding that this theory gives of the mechanism of convergence of problems of this type should lead to new and better methods of solving power system problems on a digital computer.

One form of the iteration process with acceleration can be represented by the difference equation

$$X_{n+1} = (1 - \alpha)\, X_n + (\alpha + \beta)\, G\, X_n - \beta G\, X_{n-1} \qquad (1)$$

where X is a column matrix of the correction factors found for each iteration, n is the number of the iteration, G is a matrix formed from the parameters of the system, α is an acceleration factor used when the corrections are made, and β is a factor used to multiply the correction factors from the previous iteration when they are used in the current iteration.

For a matrix such as G there usually exists a set of eigenvalues λ, and eigenvectors V, which will satisfy the equation

$$G\, V = \lambda\, V \qquad (2)$$

The V is a column vector or matrix similar in form to the X of equation 1. The λ is a constant which multiplies each term of the matrix V. For each independent eigenvalue there will be a corresponding eigenvector. These eigenvectors can be used to form a basis for the problem being solved. Thus, any arbitrary vector, such as X, can be expanded into a series using the eigenvectors analogous to the way an arbitrary periodic wave form can be expanded into components using a Fourier series. Thus, X may be represented as

$$X = c_1 V_1 + c_2 V_2 + c_3 V_3 + \ldots c_m V_m \qquad (3)$$

With linear relationships, the behavior of the system can be investigated by examining the behavior of each of the eigenvectors, much as a frequency analysis is made of a linear circuit.

Multiplication of an eigenvector by its matrix does not change its direction, but just its magnitude. If $|\lambda|$ is less than unity, the eigenvector will shrink toward zero for repeated application of the matrix. The smaller the value of the eigenvalue, the faster the eigenvector will shrink toward zero. Thus, if the initial value X_o is expanded as in equation 3, the value of X_n after n iterations will be

$$X_n = \lambda_1^n\, c_1 V_1 + \lambda_2^n\, c_2 V_2 + \lambda_3^n\, c_3 V_3 + \ldots \lambda_m^n\, c_m V_m \qquad (4)$$

where the constants c are determined by the initial value.

The difference equation given in equation 1 can be written for each eigenvector component as

$$V_{n+1} = [1 - \alpha + \lambda\, (\alpha + \beta)]\, V_n - \beta \lambda V_{n-1} \qquad (5)$$

where λ is taken to have the value corresponding to the eigenvector considered. The rate of convergence of the various eigenvector components of X can be determined by solving this difference equation. Let r be the ratio of the values of the eigenvector on successive iterations. Using this notation, equation 5 may be rewritten to form the following characteristic equation giving r in terms of α, β, and λ:

$$r^2 - [1 - \alpha + (\alpha + \beta)\lambda]\, r + \beta\lambda = 0 \qquad (6)$$

Fig. 1 shows the effect of acceleration on a system with β equal to zero. Since it is assumed that the systems studied converge without acceleration, all of the λ's must have absolute values less than unity. The rate of convergence of each eigenvector component of the error can be found from its eigenvalue using Fig. 1. For the larger positive values of λ, the acceleration increases the rate of convergence by decreasing the corresponding values of r. However, the sample systems tested each had small negative values for λ. These components die out rapidly without acceleration, but their rate of convergence is decreased by increasing α. At some value of α, these components will become the predominate ones, and further increases in the value of α will decrease the convergence rate of the system. This effect has been observed and reported by many who have worked on this problem.

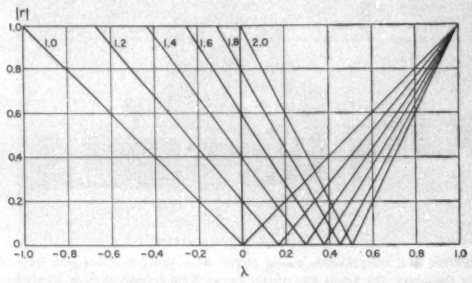


Fig. 1. Computed values of $|r|$ as a function of λ, with β equal to zero. Values of α are given beside each curve.

Digest of paper 59-1092, recommended by the AIEE System Engineering Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Fall General Meeting, Chicago, Ill., Oct. 11-16, 1959. Published in AIEE *Power Apparatus and Systems*, Feb. 1960, pp. 1590-97.

J. E. Van Ness is with Northwestern University, Evanston, Ill.

INSTITUTE ACTIVITIES

NEWEST and most modern power plant of the San Diego Gas and Electric Company, the South Bay Steam Power Plant (above, *left*) is located on a 144-acre site lying on San Diego Bay in the cities of San Diego and Chula Vista. *Above, right:* Convair-Astronautics Division of the General Dynamics Corporation manufactures the Atlas missile and its ground support equipment for the U. S. Air Force. AIEE members attending the 1960 Pacific General Meeting will have the opportunity to inspect these facilities.

1960 Pacific General Meeting Will Feature Space-Age Electricity

THE 1960 Pacific General Meeting of the AIEE will be held at the El Cortez Hotel in San Diego, Calif. Technical sessions are scheduled for Tuesday through Friday, August 9-12. The registration desk in the El Cortez Hotel will be open during the late afternoon and in the evening on Monday, August 8.

Hotel reservations are being handled by the San Diego Convention and Tourist Bureau, 924 Second Ave., San Diego 1, Calif. The Bureau may be contacted directly for information.

Highlighting the technical program will be sessions sponsored by the Aero-Space Transportation Committee on the theme "Electrical Frontiers of the Space Age." Papers are being solicited and many have been offered on the subject of "Secondary Electric Power for Missile and Space Vehicles," including nuclear power, electrochemical conversion, solar energy conversion, and thermoelectricity. Other subjects will include ionic propulsion, magnetohydrodynamics, radiation problems, support equipment, and reliability. The Pacific General Meeting Conference liaison representative for the Aero-Space Transportation Committee is E. F. Kotnik, Convair Division, General Dynamics Corporation, Department 6-140, San Diego 12, Calif.

Inspection Tours

Inspection trips have been arranged to the Convair-Astronautics Division Plant of the General Dynamics Corporation, a new and modern facility for research, development, and manufacture of the Atlas long-range missile; the South Bay Steam Power Plant, the newest and most modern power plant of the San Diego Gas and Electric Company; and the Naval Electronics Laboratory, the U.S. Navy's principal West Coast research and development center for underwater and surface electronic devices and weapons systems. Additional trips include the Stromberg-Carlson Division Plant of the General Dynamics Corporation, developers and producers of the "Characteron Tube," digital readout and computer systems, and weapon system devices; the John Jay Hopkins Laboratory; General Atomics Division of the General Dynamics Corporation, engaged in pure and applied research in atomic energy and nuclear theory, and developers of the Triga reactor for experimental research; and the University Avenue Exchange of the Pacific Telephone and Telegraph Company, the principal communication center of San Diego featuring direct dialing equipment.

Social Activities

The general program will include entertainment and special features.

A men's luncheon on Tuesday, August 9, will have as the principal speaker J. R. Dempsey, manager of the Convair-Astronautics Division, whose subject will be the "Space World of Tomorrow."

Tuesday evening will feature a dinner and theater party. Dinner will be served at the House of Hospitality, Cafe Del Rey Moro, in Balboa Park. After dinner, the Old Globe Theater will present Shakespeare's play "As You Like It."

On Wednesday, August 10, a highlight of the entertainment events will be a San Diego Harbor excursion. Boats will leave the pier at noon and go directly to the Bali Ha'i restaurant, overlooking San Diego Bay, for lunch in the Hawaiian Village. Entertainment will be provided during the luncheon by a Hawaiian dance group. After lunch, the guests will return to the boats, complete a tour of the harbor, and return to the pier at about 6:00 p.m.

There will be a banquet and dance on Thursday, August 11, in the Caribbean room at the El Cortez Hotel with entertainment by the nationally known group "The Sportsmen."

Friday, August 12, will feature a men's and women's luncheon in the Don Room at the El Cortez Hotel with a speaker and subject of general interest.

The student's program will include two technical sessions, a student luncheon, and a meeting of student counselors to discuss problems of interest.

A full program is planned for the ladies which will include a Tuesday, August 9, luncheon and fashion show in the Don Room at the El Cortez Hotel. On Thursday, August 11, a luncheon and shopping trip in La Jolla is planned. Buses will take the ladies directly to La Valencia Hotel in La Jolla for luncheon. They will depart from the El Cortez Hotel at 11:00 a.m. and on return will leave La Vallencia Hotel at 3:00 p.m. The Pool Patio at the El Cortez Hotel has been reserved for 9:00 to 11:00 a.m. and 3:00 to 4:30 p.m. for coffee hours. Bridge tables will be available.

The general committee for the 1960 Pacific General Meeting is under the chairmanship of J. F. Sinnott, of the San Diego Gas & Electric Company, San Diego 12, Calif. Requests for information concerning any part of the program may be directed to Mr. Sinnott, who will refer them to the appropriate committee chairman.

AIEE Summer General Meeting Scheduled for June 19-24 in Atlantic City

THE INSTITUTE'S Summer General Meeting, June 19-24, 1960, will be held in Atlantic City, N.J., with members of the Philadelphia Section, AIEE, acting as hosts. Headquarters will be at the Chalfonte-Haddon Hall Hotels on the boardwalk.

The week's program will open with the annual meeting on Monday, at which the newly elected officers will be announced. A feature of the session will be the presentation of the Lamme Medal to the 1959 nominee.

Technical Program

A technical program of 66 sessions has been planned for the meeting. About one half of the sessions will be devoted to some aspect of power generation or distribution, while the other half will cover such items as communications, instrumentation and control, computers, basic science, and management.

Several inspection trips are planned, including the following:

Sage Direction Center, McGuire Air Force Base, N.J. (Tuesday, June 21). Inasmuch as security clearance must be obtained for this trip, members desiring to attend should write to T. H. Story, c/o Radio Corporation of America, Building 1-3, Camden 2, N. J., giving full name and address, name of employer, and security clearance, if any. This information must be in Mr. Story's hands before June 7, 1960, so that the necessary clearances may be obtained. The trip is limited to 30 persons, and reservations will be made in the order of receipt of the necessary information.

Federal Aviation Agency, Bureau of Research and Development, National Aviation Facilities Experimental Center, Atlantic City, N. J. (Wednesday, June 22)

Eddystone Station, Philadelphia Electric Company, Philadelphia, Pa. (Friday, June 24)

Entertainment

A social program has been planned to provide those in attendance an opportunity to relax and meet their fellow members.

Included will be a cabaret party and dance on Monday night, a card party on Tuesday night, and a dinner and show on Wednesday. A moonlight boat trip will be held on Tuesday and Thursday nights.

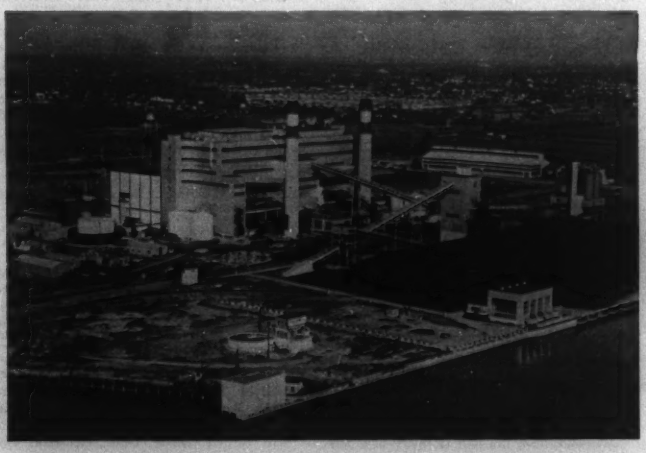
A number of activities of special interest to the ladies also have been arranged. Included in the program will be a welcoming tea, a daily coffee hour, a visit to the Fischer Greenhouses, a trip to the Renault Winery, tea at the 18th Century Smithville Inn, an authentic Hawaiian luncheon, breakfast on the sun deck, and a parade of unusual fashions.

Facilities for golf will be available.

Half-day fishing trips as well as all day trips will be arranged. Deep sea sport fishing will be available.

Reservations

The Chalfonte-Haddon Hall Hotels will act as Housing Bureau for this meeting. A list of hotels and motels available was given in the April issue of *Electrical Engineering*, p. 334. All requests for room reservations at the hotels and motels listed should be sent to Chalfonte-Haddon Hall.



ONE of the features of the Summer General Meeting will be an inspection trip to the new Eddystone Plant of the Philadelphia Electric Company. This electric generating station, in operation since early 1960, is a significant milestone in the growth of the company.

Annual Meeting

The Annual Meeting of the AIEE will be held in Atlantic City, N. J., at 2:00 p.m., Monday, June 20, 1960, during the Summer General Meeting.

At this meeting, the annual report of the Board of Directors and the reports of the Committee of Tellers on the ballots cast for the election of officers and for the proposed amendments to the AIEE Constitution will be presented. The Lamme Medal will be presented to Lee A. Kilgore (AM '29, M '37, F '45).

Such other business, if any, as may properly come before the Annual Meeting may be considered.

Signed N. S. HIBSHMAN
EXECUTIVE SECRETARY

Westinghouse Engineer Is Awarded Lamme Medal

The Lamme Medal for 1959 has been awarded to Lee Alton Kilgore (AM '29, F '45), director of engineering of Westinghouse Electric Corporation's East Pittsburgh, Pa., Division. Mr. Kilgore

L. A. Kilgore

was cited ". . . for meritorious achievements in the design of electrical machinery; more specifically, for analyses of synchronous machine reactances; for inventions of special armature windings; and for inventions and designs related to large adjustable-speed alternating-current motors."

The presentation ceremony will take place Monday, June 20, 1960, in Atlantic City, N. J., during the Summer General Meeting.

Mr. Kilgore obtained the B.S. degree in electrical engineering from the University of Nebraska in 1927, the M.S. degree from the University of Pittsburgh in 1929, and an honorary doctor's degree from Nebraska in 1956. He started with Westinghouse in 1927 in the design of large generators.

He designed the 165,000-kw 4-pole gen-

erator in 1934 for Philadelphia Electric. This remained the highest kw rating for 18 years.

In 1936, he designed the first commercial ignitron rectifier, and in 1938 was made section manager of the Large Motor Design Section of Westinghouse. He later became assistant manager of generator engineering which included at the time rectifiers and motors as well as generators. In 1954, he was made manager of engineering for the East Pittsburgh Division.

Mr. Kilgore has written several AIEE papers and other articles about generator reactances, short-circuit torques, oscillations, rectifier regulation, electric couplings, wind tunnel drives, and power supplies for large particle accelerators.

In recent years, he has conducted seminars on Human Relations for Engineers and on Creativity, and has written papers and articles on these subjects.

International Conference on Solid-State Circuits Held

More than 3,000 persons attended the recent 1960 International Solid-State Circuits Conference which was held on the campus of the University of Pennsylvania and the Sheraton Hotel in Philadelphia, Pa.

Among those in attendance were scores of solid-state specialists from abroad—Japan, Italy, France, Sweden, Hungary, Switzerland, England, and the Netherlands.

Honored guests included Leo Esaki of tunnel-diode fame; M. J. O. Strutt, chairman, electrical engineering department, Swiss Federal Institute of Technology, and C. G. Suits, vice-president and director of research, General Electric Company.

A moving tribute was paid to the late Dudley Buck during an afternoon memorial session.

A complete conference report—a 100-page letterpress book with more than 300 illustrations—covering the 43 papers presented, was distributed to all registrants. Postconference copies of this text, officially known as the *Digest of Technical Papers*, are available from: H. G. Sparks, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia 4, Pa., at $5 per copy. Remittance should be made out to: "Solid-State Circuits Conference."

Committee Members Named for 1960 Fall General Meeting

J. H. Foote, AIEE president, has appointed three members to the general committee of the 1960 Fall General Meeting.

Those appointed are: D. W. Gilman, vice-chairman, Commonwealth Edison Company, Chicago, Ill.; E. C. Carlson, secretary, Illinois Bell Telephone Company, Chicago, Ill.; and J. Agosta, treasurer, Commonwealth Edison Company, Maywood, Ill.

The committee members were named upon recommendation of the committee chairman, L. E. Randall.

In the AIEE Organization Manual for 1959-60, on p. 153, Bylaw 33 outlines the duties of the General Meeting Committee, and on p. 203 are recorded the Institute's policies for the conduct of General Meetings.

Solid-State Electronics Is Topic of Workshop Program

A 1½-day tutorial program on solid-state electronics is to be presented at Purdue University on June 23-24 under the joint sponsorship of the Institute of Radio Engineers Professional Group on Education and the Electrical Engineering Division of the American Society for Engineering Education (ASEE).

The program for the event has been announced by Dr. J. G. Truxal and Dr. J. H. Mulligan, Jr., respective chairmen of the two groups. Dr. W. B. Boast, Iowa State University, is chairman of the Program Committee for the workshop. Other members are Dr. R. H. Mattson, Iowa State University; Dr. J. L. Moll, Stanford University; Dr. R. L. Pritchard, Texas Instruments, Inc., and G. R. Madland, Motorola Semiconductor Products Division.

Designed primarily for electrical engineering educators, but open to all interested parties, the workshop will include nine papers arranged in three sessions as follows:

Thursday, June 23

Characteristics of Electrons in Solids. *J. M. Shive*, Bell Telephone Laboratories, Inc.

Afternoon Session

Semiconductors. *R. H. Mattson*, Iowa State University

Electrical Properties of Semiconductor Materials. *W. G. Dow*, University of Michigan

Friday, June 24

Morning Session

Diodes. *M. O. Thurston*, Ohio State University

Transistors. *J. M. Early*, Bell Telephone Laboratories, Inc.

Friday, June 24

Afternoon Session

Energy Conversion Devices. *S. J. Angello*, Westinghouse Electric Corporation

Low-Temperature Devices. *A. L. McWhorter*, Lincoln Laboratories, Massachusetts Institute of Technology

Other Solid-State Devices. *J. L. Moll*, Stanford University

Further details regarding program information may be obtained from Dr. W. B. Boast, Iowa State University, Ames, Iowa. Information regarding living accommodations for the meeting may be obtained from Dr. T. F. Jones, Purdue University, Lafayette, Ind.

The workshop on solid-state electronics is but one of the events of the Electrical Engineering Division scheduled for the ASEE annual meeting at Purdue University. On Monday, June 20, there will be a session on "Learning Machines" under the chairmanship of Prof. A. V. Eastman of the University of Washington. The following papers will be presented:

The Automization of Socrates. *D. Cook*, Purdue University

Design Techniques of Automatic Teaching Machines. *H. A. Baldwin*, University of Arizona

Teaching Elementary Stress Analysis by Machine. *A. F. Johnson, D. J. Mayhew*, University of Utah.

MARI—A Simple Electrical Teaching Device. *M. Crosby, O. Lancaster*, Pennsylvania State University

On Monday evening at 8:00 p.m., there will be a panel discussion on the theme "The Role of the Electrical Engineering Division in the Next Decade." Participants will be Dr. Boast, head, electrical engineering department, Iowa State University; Dr. R. K. Moore, head, electrical engineering department, University of

Lewis Winner

A PANEL of tunnel-diode experts met for an informal discussion session at the Sheraton Hotel during the 1960 International Solid-State Circuits Conference. They are (*left to right*): S. L. Miller, International Business Machines; J. J. Tiemann, General Electric Company; G. C. Dacey, Bell Telephone Laboratories; D. E. Thomas, Bell Telephone Laboratories; H. Somers, Radio Corporation of America, and Leo Esaki.

AIEE Future Meetings

North Eastern District Meeting*
Sheraton Biltmore Hotel
Providence, R.I.
May 2-4, 1960

AIEE-IRE-ACM Western Joint Computer Conference*
Jack Tar Hotel
San Francisco, Calif.
May 3-5, 1960

AIEE-IRE-U of V Educational Frontiers in Biomedical Engineering Symposium*
University of Vermont
Burlington, Vt.
May 5-6, 1960

Spring Textile Conference*
Georgia Institute of Technology
Atlanta, Ga.
May 5-6, 1960

AIEE-IRE-EIA-WCEMA Electronic Components Conference*
Hotel Washington
Washington, D. C.
May 10-12, 1960

Rural Electrification Conference*
Sheraton-Fontenell Hotel
Omaha, Nebr.
May 10-12, 1960

Appliance Technical Conference*
Leland Hotel
Mansfield, Ohio
May 16-17, 1960

Annual Cement Industry Technical Conference*
Pfister Hotel
Milwaukee, Wis.
May 17-18, 1960

AIEE-ISA-ARS-IAS National Telemetering Conference*
Marimar Hotel
Santa Monica, Calif.
May 23-26, 1960

World Power Conference
Instituto Nacional de Industria
Madrid, Spain
June 5-9, 1960

Summer General Meeting*
Chalfonte-Haddon Hall
Atlantic City, N. J.
June 19-24, 1960

AIEE-IRE-NBS Standards & Electronic Measurements Conference*
National Bureau of Standards Laboratory
Boulder, Colo.
June 21-22, 1960

Pacific General Meeting
El Cortez Hotel
San Diego, Calif.
August 8-12, 1960
(Final date for †TP—May 10, ‡CP Syn.—May 20, CPMs—June 3)

Aero-Space Transportation Conference
El Cortez Hotel
San Diego, Calif.
August 8-12, 1960
(Final date for †TP—May 10, ‡CP Syn.—May 20, CPMs—June 3)

AIEE-AIChE-IRE-ISA-ASME Joint Automatic Control Conference
Kresge Auditorium
Massachusetts Institute of Technology
Cambridge, Mass.
September 6-9, 1960
(Final date for †TP—June 9, ‡CP Syn.—June 24, CPMs—July 5)

AIEE-ASME Engineering Management Conference
Morrison Hotel
Chicago, Ill.
September 14-16, 1960
(Final date for †TP—June 16, ‡CP Syn.—July 1, CPMs—July 11)

AIEE-IRE Industrial Electronics Conference
Sheraton-Cleveland Hotel
Cleveland, Ohio
September 21-22, 1960
(Final date for †TP—June 23, ‡CP Syn.—July 8, CPMs—July 18)

AIEE-ASME National Power Conference
Bellevue-Stratford Hotel
Philadelphia, Pa.
September 21-23, 1960
(Final date for †TP—June 23, ‡CP Syn.—July 8, CPMs—July 18)

Petroleum Industry Conference
Skirvin Hotel
Oklahoma City, Okla.
September 25-28, 1960
(Final date for †TP—June 27, ‡CP Syn.—July 12, CPMs—July 22)

Fall General Meeting
Morrison Hotel
Chicago, Ill.
October 9-14, 1960
(Final date for †TP—June 10, ‡CP Syn.—July 21, CPMs—Aug. 5)

AIEE-IRE-EIA-SMPTE National Electronics Conference
Sherman Hotel
Chicago, Ill.
October 10-12, 1960
(Final date for †TP—July 12, ‡CP Syn.—July 27, CPMs—Aug. 5)

Nonlinear Magnetics and Magnetic Amplifier Conference
Bellevue-Stratford Hotel
Philadelphia, Pa.
October 26-28, 1960
(Final date for †TP—July 28, ‡CP Syn. Aug. 12, CPMs—Aug. 22)

AIEE-IRE-ISA Electrical Techniques in Medicine and Biology Conference
Sheraton-Park Hotel
Washington, D. C.
October 31—November 2, 1960
(Final date for †TP—Aug. 2, ‡CP Syn.—Aug. 17, CPMs—Aug. 26)

Power Industry Computer Application Conference
Chase Hotel
St. Louis, Mo.
November 9-11, 1960
(Final date for †TP—Aug. 11, ‡CP Syn.—Aug. 26, CPMs—Sept. 5)

AIEE-AIP Magnetism and Magnetic Materials Conference
Hotel New Yorker
New York, N. Y.
November 14-17, 1960
(Final date for †TP—Aug. 16, ‡CP Syn.—Aug. 31, CPMs—Sept. 9)

Winter General Meeting
Hotel Statler
New York, N. Y.
January 29-February 3, 1961
(Final date for †TP—Oct 31, ‡CP Syn.—Nov. 10, CPMs—Nov. 25)

South East District Meeting
Jung Hotel
New Orleans, La.
April 5-7, 1961
(Final date for †TP—Jan. 5, CPMs —Jan. 30)

Great Lakes District Meeting
Hotel Pick-Nicolett
Minneapolis Minn.
April 19-21, 1961
(Final date for †TP—Jan. 19, CPMs —Feb. 13)

North Eastern District Meeting
Statler Hotel
Hartford, Conn.
May 17-19, 1961
(Final date for †TP—Feb. 16, CPMs—Mar. 13)

*Final date for submitting papers—closed

†TP—Transactions Paper
‡CP Syn.—Conference Synopsis
CPMs—Conference Manuscript
DPMs—District Manuscript
(District Paper Synopses should be directed to the District Meeting Committee)

Transactions and conference papers must conform to the requirements in *Author's Guide*
For a copy, write to E. C. Day, AIEE, 33 W. 39th St., New York 18, N. Y.

Cleveland Section Exhibit

ANNUAL Engineer's Week in Cleveland, Ohio, was observed recently by the Cleveland Section, AIEE, with a display at the Cleveland Engineering and Scientific Center. K. L. West, public relations chairman of the Section, is shown viewing the display.

New Mexico; and Dr. J. H. Mulligan, Jr., head, electrical engineering department, New York University.

On Tuesday, June 21 at 2:00 p.m., there will be a session devoted to probability and statistics in electrical engineering under the direction of Dr. J. S. Johnson, dean of engineering, Wayne State University. The four papers scheduled for this meeting are:

Mathematics Approach to Probability and Statistics Instruction for Electrical Engineers. *J. G. Brainerd*, University of Pennsylvania

Electrical Engineering Approach to Probability and Statistics Instruction for Electrical Engineers. *R. J. Schwarz*, Columbia University

Random Process Studies and Information Theory. *F. C. Rideout, A. Burr*, University of Wisconsin

Reliability of Electronic Equipment. *C. A. Krohn*, Motorola, Inc.

The AIEE Summer General Meeting coincides with the annual ASEE meeting at Purdue on June 19-25. The AIEE Education Committee has, therefore, elected not to sponsor competing programs at the Atlantic City meeting but rather to encourage all electrical engineers interested in education to attend the ASEE meeting at Purdue.

Technical Program Given for Cement Industry Conference

The Cement Industry Technical Conference, sponsored for the 2nd year by the AIEE Cement Industry Subcommittee, will be held May 17-19, 1960, in the Pfister Hotel, Milwaukee, Wis.

The tentative technical program for the conference follows:

Tuesday, May 17

10:30 a. m. Maintenance and Safety

Tentative Moderator: H. P. Cassel

Electrical Maintenance in Cement Plants. *R. C. White*

Recommended Safety Practices Pertaining to Electric Equipment in Cement Plants. *H. P. Cassel*

1:30 p. m. Automation

Moderator: A. H. Huelsman

A Review of Automatic Sampling—What Has Been Done To Obtain Truly Representative Samples. *R. J. Jager, J. A. Mitchell*

Some Fundamental Concepts of Regulating Circuits as Applied to the Cement Industry. *J. H. Rittenhouse, A. K. Raney*

The 1960 Status of the Riverside Computer Installation. *L. W. Weeks, R. L. Boulden*

Developments in X-Ray Chemical Controls in the Cement Manufacturing Process during 1959 and 1960. *Bruce Kester, G. B. Moore, W. F. Loranger*

Process Instruments as an Aid to Automating Cement Plants. *J. H. Herz*

The Use of a Magnetic Flowmeter for Automatic Metering of Slurries. *Bruce Kester*

Wednesday, May 18

9:00 a. m. Drives

Requirements for Cement Plant Overhead Storage Cranes from a User's Viewpoint. *L. E. Swanson*

Selection of Electric Equipment for Cement Plant Storage Cranes. *A. A. Rutowski*

Typical Accuracies Required for Adjustable Speed Feeders in the Cement Industry. *J. B. Woodward, R. H. Striker*

Comparison of Basic Drive Types for Adjustable Speed Feeders in Cement Plants. *Thord Offrell*

Suggested Standards for Electric Drives in the Cement Industry. *C. E. Roberts*

1:30 p. m. Distribution

Moderator: G. E. MacDonald

Preliminary Suggested Recommendations for Cement Plant Power Distribution. *A. C. Lordi*

Typical Application Consideration for Cable in Cement Plants. *W. A. Brown, D. L. Watkins*

Typical Installation Practices for Cable in Cement Plants. *G. I. Burner*

Typical Application and Installation Practices for Cables and Overhead Lines in Cement Plant Quarries *W. A. Reynolds, W. T. Walker*

Interesting Features of the Electric Equipment in Marquette's Milwaukee Plant. *G. H. Ember*

Conference Papers Open for Discussion

Conference papers listed below have been accepted by AIEE *Transactions* and are now open for written discussion until May 27. Duplicate double-spaced typewritten copies of each discussion should be sent to E. C. Day, Assistant Secretary for Technical Papers, AIEE, 33 W. 39 St., New York 18, N. Y., on or before May 27.

60-107 **Mechanical Loadings on Circuit Breaker Bushings.** *E. F. Huston, E. B. Rietz*

60-165 **Equivalent Circuits and Performance Calculations of Canned Motors.** *P. D. Agarwal*

60-170 **Armature Tooth Pulsations Eddy Current.** *M. J. Pasculle*

Preprints may be purchased at 50¢ each to members, $1.00 to nonmembers, if accompanied by remittance or coupons. Please order by number and send remittance to: AIEE Order Department, 33 W. 39th St., New York 18, N. Y.

Electronic Components Conference Slated for May

This is the 10th year that four of the nation's leading engineering and manufacturing organizations have joined together to sponsor the Electronic Components Conference. The 1960 conference will be held May 10-12 at the Washington Hotel, 15th and F Streets, N.W., Washington, D. C.

The sponsors are: AIEE, the Electronic Industries Association (EIA), the Institute of Radio Engineers (IRE), and the Western Electronic Manufacturers Association (WEMA).

The conference theme "Electronic Com-

ponents: Art and Science" will set the stage for the presentation of ideas, concepts, and developments looking to the future.

Opening the conference will be a session called "Quo Vadis, 1970," during which leaders in the field will anticipate future developments and lay down requirements that must be met in the next decade. These requirements include systems needs, components needs, and research.

Another feature of the conference will be the first report of the Department of Defense component reliability program by the men who formulated the program and supervised its progress.

In commemoration of the 100th anniversary of the U. S. Army Signal Corps, the conference will devote one session to a review of the past and forecast of future Signal Corps requirements.

Maj. Gen. E. R. Cook, deputy chief signal officer, will address a special luncheon session on Wednesday, May 11. The luncheon also will feature a special papers award and will honor the presidents of the organizations sponsoring the conference.

General chairman of the 1960 conference is R. L. Henry of ACF Electronics, Alexandria, Va. The conference steering committee includes: G. B. Devey, technical program chairman, Sprague Electric Company; J. P. Nigro, local arrangements, National Bureau of Standards; A. E. Zdobyz, finance, ACF Electronics; A. E. Javitz, publications, *Electrical Manufacturing* magazine; and H. H. Rosen, public relations, National Aeronautics and Space Administration.

Representing the sponsoring organizations are: R. S. Gardner, AIEE; P. H. Cousins, EIA; J. J. Drvostep, IRE; and R. L. Paullus, WEMA. Also on the conference committee are: E. J. Nucci, Department of Defense; Leon Podolsky and A. W. Rogers, U. S. Army Signal Corps; W. T. Sumerlin, Philco Corporation; and F. E. Wenger, U. S. Air Force—Air Research and Development Command.

Philadelphia Auxiliary Presents 6th Education Award

The Women's Auxiliary to the Philadelphia, Pa., Section, AIEE, has presented $400 to the electrical engineering department of Drexel Institute of Technology of Philadelphia.

The purpose of this gift, known as the Education Award, is to help further electrical engineering education. The money, which will be used to purchase books or laboratory equipment, is given annually to one of the accredited schools of electrical engineering in the Philadelphia Section area.

The funds are raised by annual card parties sponsored by the auxiliary. More than $2,200 has been contributed for this purpose in the 6 years since the award was started.

The presentation was made at Drexel Institute by Mrs. E. A. Bailey, chairman of the auxiliary.

The auxiliary celebrated its 12th anniversary in April and has 235 members. It will take an active part in helping the Philadelphia Section entertain the AIEE members and their wives at the 1960 Summer General Meeting to be held at Atlantic City, N. J., in June.

Two Sessions Are Planned on Data Transmission Subjects

Two sessions on data transmission are being planned as a joint item on the program of the 1960 National Electronics Conference (NEC) and the AIEE Fall General Meeting. The Communication Theory Committee and the Data Transmission Committee are co-operating with Professional Groups of the Institute of Radio Engineers and the NEC Program Committee to make this an event of considerable professional interest.

The broad purpose of the meeting is to consider the great variety of recently invented digital transmission systems against simultaneously made advances in theory. Large gaps exist in the published literature on the performance of high-speed digital systems, of which those used in the Distant Early Warning line, SAGE, Strategic Air Command, and Ballistic Missile Early Warning System are indicative of future systems which may find wide application to industrial and managerial functions. A large gap is to be bridged also between theoretical coding schemes and their utilization. Inadequate published information exists on models of practical channels on which the design of modulation and coding schemes can be based. It has become increasingly evident that such data are being garnered at a number of different places. The planned meeting should provide for an exchange of such information in the interest of the communications theorist, the systems designer, and the user.

Papers to be presented will be concerned in general with current digital transmission developments with rates on the order of kilobits per second. It is hoped that the special problems of, for instance, railroad signaling, power-line carrier, and pipeline communications will be covered adequately. The present plan is to reserve the first session for the more tutorial treatment of media characterization, codes, and modulation systems. The second session would include field measurements on noise and performance and discussions on mathematical models for noise and error.

In order to create the greatest possible opportunity for discussion, it is planned to have all papers available in preprinted form at the conference. The Papers Committee reports that a sufficient number of papers already are available to make this feasible. However, additional papers from the fields outlined herein are solicited. Prospective authors should send an abstract and title as soon as possible to Dr. H. Sherman, Massachusetts Institute of Technology, Lincoln Laboratory, P.O. Box 73, Lexington 73, Mass.

AIEE Plans Conference on Domestic Appliances in May

The 11th Annual Appliance Technical Conference will be held May 16-17, 1960,

PRESENTATION of the Education Award of $400 for the electrical engineering department was made by Mrs. E. A. Bailey, chairman of the Women's Auxiliary to the Philadelphia Section, to Dr. James Creese, president of Drexel Institute of Technology. Shown are *(left to right)*: Dr. F. B. Haynes, head of electrical engineering at Drexel Institute; Dr. Creese; Mrs. Bailey; Mrs. V. L. Cox, ways and means chairman; Mrs. G. B. Schleicher, education chairman; Mrs. W. N. Gittings, historian; Mrs. C. T. Pearce, ways and means vice-chairman; and Mrs. R. S. Hewett, member of the education committee.

in the Mansfield-Leland Hotel, Mansfield, Ohio.

Sponsors of the conference are the Subcommittee on Domestic Appliances, AIEE, and the Mansfield, Ohio, Section of AIEE.

The keynote address will be given by R. E. Brooker, president, Whirlpool Corporation, on the topic "Should engineers and will engineering require changes in top management policy thinking—are engineers in a position to help answer that question and, if so, what must they do to accept the challenge?"

The general areas of activity of the conference will be as follows:

Session 1—Technical Papers

Chairman: M. A. Fuller, research engineer, Whirlpool Corporation, St. Joseph, Mich.

Session 2—Technical Papers

Chairman: Warren Kindt, engineering manager, component design, range department, General Electric Co.

Session 3—Plant Tours

Chairman: E. O. Morton, manager, laundry engineering department, Westinghouse Electric Corp.

Session 4—Luncheon

Address by B. A. Chapman, executive vice-president, Kelvinator Division, American Motors Corp., on the topic "Annual model changes vs. continual incorporation of significant technological advances."

Chairman: W. R. Milby, director, consumer services, Detroit Edison Co.

Session 5—Technical Papers

Chairman: Dana Chase, editor, *Metal Products Manufacturing* Magazine

Local Committee Chairman: J. G. Idle, Westinghouse Electric Corp.

The tentative schedule of papers follows:

Mechanical Problems of Electrical Contacts and Connections.

Standardizing Small Motors.

Matching Motors to Appliance Loads.

Ultrasonics in Fabric Washing.

Thermoplastics in Appliance Design.

Specifying Centrifugal Pumps for Appliance Applications.

Magnetic Door Closures for Refrigerators and Freezers.

Calibration and Quality Control Testing of Thermostats.

Control System Design for Refrigerators.

Engineering Audit of Design Quality.

Positive Quality Control.

Customer Service—A Technical "Feedback" for Engineering and Quality Control.

A Hard Coating Process for Aluminum.

A Simple Plastic Part Fabricating Process.

A Nontimed "Proportional Dryer Control."

An Automatic Surface Unit Control for Ranges.

Combining Microwave and Infrared Cooking in a Single Oven Cavity

A Plug-in Surface Cooking Unit.

An Immersible Percolator Design.

Wire Termination Design.

Any person who has not attended previous conferences and is interested in this meeting should advise R. A. Rieser of the Ohio Brass Co., Mansfield, Ohio, registration chairman.

75th Anniversary of AIEE Celebrated by Spokane Section

The Spokane, Wash., Section celebrated the 75th Anniversary of the AIEE with a 2-week long historical display in the lobby of the Davenport Hotel to depict the development and growth of the electrical industry in the past 75 years. The Section also sponsored an essay contest for area high school students on the subject of "The Next 25 Years in a Century of Electrical Progress."

It was planned that this activity would most appropriately emphasize the anniversary theme "75 Years—A Prologue to the Future."

Beginning early in December and running for nearly 2 weeks, the hotel display included exhibits furnished by local industry and educational institutions. A variety of items showed the improvements in design, application, and utilization of electricity. Exhibits furnished by the University of Idaho and Washington State University showed the changes in the electrical engineering curriculum and teaching aids during the last 50 years.

The essay contest challenged the imagination of the scientists and engineers of the future to predict the developments expected in the remaining 25 years of the century that began with the organization of AIEE in 1884. Prizes were awarded to the top three entries and seven others received honorable mention certificates.

DEPICTED in this display is the history of lighting, an exhibit in the lobby of the Davenport Hotel arranged to celebrate the 75th Anniversary of the AIEE. Lewis & Clark High School students, John Keil and Marilee Hart, are instructed by W. A. Morgan, chairman of the Spokane Section.

AIEE Members To Present Technical Papers at CIGRE

AIEE members representing electric utilities and electrical manufacturing firms will author eight of the 130 technical papers on electric power generation and transmission that will be presented at the 18th biennial meeting of the International Conference on Large Electric Systems to be held in Paris, France, June 15-25, 1960.

The papers are sponsored by the U. S. National Committee, a group of 19 leading authorities in power system engineering, who guide and direct United States participation on this oldest and largest of international organizations for interchange of engineering information among nations.

Known among engineers as CIGRE, the initials of its French name—Conference Internationale Des Grands Reseaux Electriques—the Paris-based conference was founded in March 1921 to study advances in the engineering of large high-voltage electric systems. CIGRE now has more than 2,400 members from 50 countries, of which 314 are from the United States.

The 130 papers to be presented at the 1960 Paris conference fall into four general groups. Section 1—generation, transformation, and circuit interruption; Section 2—construction, insulation, and maintenance of overhead and underground lines; Section 3—operation, protection, and interconnection of power systems; and Section 4—power transmission at voltages over 220 kv.

In the program for the Paris conference, papers by United States engineers will present important new developments in American high-voltage transmission practice. Among them will be reports on the 345-kv transmission system of the American Electric Power Company and Ohio Valley Electric Company, details of the 750-kv Project EHV research program of General Electric Company in Western Massachusetts, as well as a paper by engi-

neers of Consolidated Edison Company of New York on protection of turbine generators. Other United States authors will discuss planning of large power systems, the design and testing of transformers and circuit breakers, and the application of insulators to high-voltage lines.

Included among the presentations by United States power experts will be reports by Americans who are chairmen of two of the 18 CIGRE International Study Committees. These committees co-ordinate the collection of specialized technical information among member countries and are made up of outstanding international authorities in each specialized field. The United States has 17 representatives and 76 advisors on 17 of CIGRE's 18 Study Committees in addition to the two chairmen.

Selection of the subjects and authors of technical papers to be offered by United States members of CIGRE at the 1960 Paris conference was made by the 6-man United States Technical Subcommittee under the direction of C. W. Franklin, consulting electrical engineer, Consolidated Edison Company of New York, Inc.

All delegates to the CIGRE conference are required to register through the U. S. National Committee. Registration forms, obtainable from the Committee, must be returned with the registration fee ($50 for permanent members, $62 for nonmembers) to the Secretary, U. S. National Committee—CIGRE, 2 Broadway, New York 8, N. Y. English language translations of technical papers are distributed in advance of the Paris conference to all registered delegates as well as to permanent members of CIGRE.

Technical sessions of the Paris conference will be held at Fondation Berthelot, 28 bis, Rue Saint-Deminique, close to the Assemblee Nationale. There will be 23 technical and three general sessions during the 10-day conference.

Technical papers which will be offered by United States delegates to the conference are as follows:

Dielectric Test on Large High-Voltage Transformers. *J. R. Meador*, General Electric Co.

Power Circuit Breaker Testing in the Field. *E. C. Starr, E. J. Harrington*, Bonneville Power Administrations.

A New Concept in Circuit Breaker Design. *T. C. Browne, Jr., W. M. Leeds*, Westinghouse Electric Corp.

Design and Application of Insulators for Difficult Service Environment. *A. D. Lantz, J. J. Taylor*, Ohio Brass Co.

Co-ordinated Over-all Generating Unit. Protection by Automatic Tripping. *H. A. Bauman, W. C. Beattie, J. M. Driscoll, P. T. Onderdonk, R. L. Webb*, Consolidated Edison Co. of N. Y.

New Horizons in System Planning. *J. K. Dillard*, Westinghouse Electric Corp., East Pittsburgh, Pa., *H. K. Sels*, Public Service Electric and Gas Co.

Project EHV. *P. A. Abetti*, General Electric Co.

The 345-Kv Transmission System of the American Electric Co., and the Ohio Valley Electric Corp. *F. M. Porter, H. P. St. Clair*, American Electric Power Service Corp.

Wear Your ◆ AIEE Badge

Lehigh Valley Section Meeting

AUTHORS of technical papers judged the best of those presented by Lehigh Valley Section members during 1959 were presented with certificates and prize money at a Section meeting recently. *Below:* Prize Committee Chairman J. E. Roth (*center*) made the presentation. He is shown with the prize winners (*left to right*): A. O. Thomas, Pennsylvania Power & Light Company, who wrote "Calculation of Transmission Line Impedance by Digital Computer"; A. C. Lordi, Westinghouse Electric Corporation, and J. F. Hower, Lehigh Portland Cement Company, who coauthored "Principles of Electrical Power Distribution System in Lehigh's Miami Plant"; and W. R. Smith, Pennsylvania Power & Light Company, author of "Standard Substation Designs Are Not Permanent," first prize winner. *Right:* During the meeting, the past chairman's pin and certificate were presented by Section Chairman M. F. Rosol (*left*) to I. M. McNair. The featured speaker of the meeting was I. E. Lemperi, Westinghouse Electric Corporation, who spoke on "Practical High Fidelity for the Home—Monaural and Stereophonic."

Student Branch Co-ordinator Appointed to Headquarters Staff

J. W. Morrison, Jr., has been appointed Student Branch co-ordinator in the AIEE headquarters staff, as of March 1, 1960. The appointment was announced by N. S. Hibshman, executive secretary of the AIEE.

A former resident of Aurora, Ohio, and a graduate of the Massachusetts Institute of Technology (MIT), Mr. Morrison is responsible for staff services to the 164 AIEE Student Branches in this country, Canada, and Puerto Rico. He works closely with the Student Branches Committee, the student counselors, and the Student Activities Committees in the 14 Districts of the Institute.

Mr. Morrison was graduated from MIT in 1945. He was a freshman at Lehigh University, went to MIT on the Navy V-12, and has done graduate work at Case Institute, the University of Akron, MIT, and Western Reserve University.

His industrial experience includes research in analog computer applications and work in missile guidance and control systems. In the latter capacity, he co-designed and did the engineering co-ordination on adapting a T-33 jet trainer as a simulated missile, and had systems responsibility for a unique missile altitude control system during its development flight test phase.

Rappoport

J. W. Morrison, Jr.

CONCRETE forms (*left*) rise above the fence surrounding the site of the United Engineering Center on their way to becoming part of the new 18-story home of the engineering profession. In the background is the United Nations building. A giant shovel bites into the earth (*right*) on this site. This scene, taken in March, shows rapid progress being made in the construction of the building. The first concrete was poured in early February.

Status of Construction of Engineering Center Reported

"Every phase of construction of the United Engineering Center is on schedule or a little bit ahead"—that was the report from the construction site at 47th St. and United Nations Plaza in New York on April 1. Excavation for footings was virtually complete and about half of the basement walls were already poured. Plumbing work was begun and floor slabs scheduled for pouring late in the month.

Steel erection is scheduled to begin early in May.

Meanwhile, in the fund-raising campaign for the Center, end-of-month returns show that the American Institute of Consulting Engineers (ASCE) has joined the American Institute of Chemical Engineers in having achieved 100% of its quota, and the American Institute of Industrial Engineers has passed the 85% mark.

The four societies with highest quotas remaining to be achieved had reached, as of March 25, the following percentages of their quotas:

ASCE=91% achieved
AIEE=91% achieved
ASME (American Society of Mechanical Engineers)=84% achieved
AIME (American Institute of Mining, Metallurgical and Petroleum Engineers) =74% achieved

The industrial campaign has achieved approximately $4.9 million in gifts and pledges.

Details of construction specifications recently made public by United Engineering Trustees reveal that the exterior of the structure will be sheathed in stainless steel and glass, with the exception of portions of the lower floors and the west end of the tower, which will be covered in limestone. Window washing will be facilitated through a motorized scaffold, suspended from the roof.

The lobby, with the main entrance on 47th St., will be walled in marble with floors of terrazzo. Two corridors lead from the lobby to meeting rooms and dining rooms on the first floor. On the east side, a display area of 6,235 square feet will feature ceiling-height windows. Approximately half the ceiling height will be 15 feet with the other half rising 22 feet 3 inches. Movable partitions in this area, as well as in meeting rooms and dining rooms will permit adaptation of space to special purposes.

Elevators, along the west wall, will be capable of speeds of 700 feet per minute. Four elevators will be installed to meet present needs, with provision for two more in the future if needed.

Provisions for future expansion of office space has also been made on the northwest side of the building. The expansion could add as much as 8,500 square feet of floor space from the 3rd to the 8th floors and 6,000 square feet from the 9th to the 12th.

Altogether, the Center will rise 283 feet above street level, including 18 floors of office space and two of mechanical equipment. A basement provides space for dining room seating 350, serving counter and an employees' lounge. Other basement space is devoted to kitchen, mechanical and electric equipment, and maintenance facilities.

The Engineering Societies Library and Engineering Index will be housed on the second floor, with reading room facilities for 74 persons at a time and stack facilities (including a small elevator) for an ultimate capacity of 225,000 volumes.

Air conditioning, with zoned control, will operate throughout the building. A light level of 75 foot candles will be maintained in all offices.

Atomic Power Plant's Use of Analog Computer Reviewed

S. N. Irwin, Detroit engineering consultant, and R. R. Kley (AM '54) of Holley Carburetor Company, Warren, Mich., are scheduled to present to the 1960 Western Joint Computer Conference a report on the development of the operating control system for the Enrico Fermi Atomic Power Plant being built near Monroe, Mich. Their paper, entitled, "Analog Computer Serves as both Systems Analysis Tool and Operator Training Facility for Enrico Fermi Atomic Power Plant," will be presented May 5 before the group of computer specialists meeting in San Francisco, Calif.

The analog computer used by Holley Carburetor Company in this control system work is an electronic representation of the Enrico Fermi sodium-cooled fast breeder reactor and other power plant components. It enables plant performance to be studied in detail before the reactor is actually started up and the plant goes into operation. The same electronic device has also been adapted by Holley for training power plant operators who will be ready to take over when the real plant "goes critical."

Mr. Irwin and Mr. Kley, who have worked on the control system development project from its inception at Holley in March 1957, will explain to the conference audience how they and the Holley staff assembled electronic equivalents of the fast breeder reactor, heat exchange system, once-through steam generators, feedwater and steam flow system, and then interconnected these elements in their proper sequence to form an electrical working model of the whole plant. Observing the behavior of this model, they were able to plan control concepts for the Fermi plant far in advance of its actual operating date. On the basis of these control concepts, the elements of an automatic control system were devised. Once this control hardware had been designed, it was also simulated electronically and the simulation added to the computer representing the plant.

Control consoles duplicating the control panel layout in the actual plant were connected to the analog simulator (computer) to adapt it to power plant operator training. Working from this console, trainees get the "feel" of plant operating

characteristics, learn to meet emergencies, and practice standard operating procedures using both manual and automatic control. The training program now under way at Holley Carburetor Company will supplement PRDC training elsewhere and assure the availability of several skilled operating teams before the plant is ready to go into operation.

The facility in its present form will be transferred to the reactor site on the shore of Lake Erie on or about May 15 and will become a vital part of the on-site training facilities. At the same time the basic simulation as set up on the analog computer will remain available for any future systems analysis needs.

Designed by Atomic Power Development Associates, Inc., Detroit, the Enrico Fermi Power Plant is being constructed under the Atomic Energy Commission's Power Demonstration Reactor Program. The nuclear portion of the plant is being built by PRDC, a nonprofit group of 18 electric utilities and 7 manufacturing firms. Detroit Edison is building the conventional turbine-generator portion of the plant which it will operate on superheated steam produced by the reactor's thermal energy. The Fermi Plant is designed to produce 100 mw of electrical power and is scheduled for startup in December 1960.

Mr. Irwin, formerly chief engineer, Electro-Mechanical Division, Holley Carburetor Company, is now a consultant on systems engineering.

Mr. Kley is manager of the Data Processing and Systems Analysis Section of the Holley Carburetor Company, research department.

EDUCATION in engineering was the subject of the Boston Section's February meeting. The featured speaker was Dr. G. S. Brown of MIT (*right*). Attending the meeting were (*left to right*): Leslie Weed, AIEE Northeast District 12 secretary and president of the Engineering Societies of New England, and P. H. Ware, president of the Boston Section, AIEE.

MIT Dean Addresses AIEE Boston Section Meeting

Dr. G. S. Brown, dean of the School of Engineering at the Massachusetts Institute of Technology (MIT), spoke before the Boston Section, AIEE, at the February meeting. A well-known authority in the field of engineering education, Dr. Brown is the author of the paper "Education for Expanding Horizons in Electric Power," which appeared in the February 1960 issue of *Electrical Engineering*, pp. 119-23.

Speaking on the topic "Electrical Engineers' Great Challenge—the 1960's," Dr. Brown said that the crucial task in the '60's is to adjust to the demands and consequences of advancing technology and that the engineer is the instigator and cause of change.

Pointing the way to this adjustment is positive reappraisal of engineering education course content with intensive emphasis on fundamentals. In the field of electrical engineering, these fundamentals would be the charge carrier, magnetic fields, and interaction of fields.

Dr. Brown stated that the capability of youth is underestimated and that the child is not given the respect for the intellectual aspects of education. Leadership of high caliber is practically nonexistent in today's college.

Commenting on the Ford Foundation grant to MIT for new advances in engineering education, Dr. Brown indicated that approximately one half of the $9 million grant would be allocated for endowment of professors in various fields of research and that the other half would be devoted to the study of curricula and the development of "core" programs in the fields of engineering education.

Recommendations Given for Technological Advances

Scientific and technological advance could be speeded if this country's research and development were conducted under conditions which would stimulate greater originality.

This is the conclusion reached by 51 of the nation's top scientists, researchers, and educators, who conferred for 2 days during December 1959 at Worcester Polytechnic Institute under auspices of the National Science Foundation in co-operation with 15 leading scientific and engineering societies, one of which is the AIEE.

They pondered the thought that research people too easily become preoccupied with goals of relatively small dimensions which promise little in significant discovery. Progress will be influenced far more by those who strike out vigorously for breakthroughs on the frontiers of science.

It was felt that the young researcher is steered in the direction of conservatism by his education, research support, professional societies, as well as social and cultural environment.

These tendencies, it was stated, serve to produce small steps in the extensions of knowledge. More rapid and efficient progress might reasonably be expected if greater encouragement were given for young people to strive for the distant goals. To the latter end, a conference resolutions committee recommended that colleges and universities:

1. Develop educational programs which require the student to exercise a high degree of originality and independence of thought. The student should be challenged with creative experiences throughout his entire educational experience.

2. Bring talented youth into stimulative personal association with leading scientists and engineers.

3. Encourage more venturesome attitudes in doctoral research. A graduate student should not necessarily be penalized by failure to complete distant objectives.

4. Develop institutional policies which provide an encouraging environment for venturesome research. This starts with faculty members who themselves are creative.

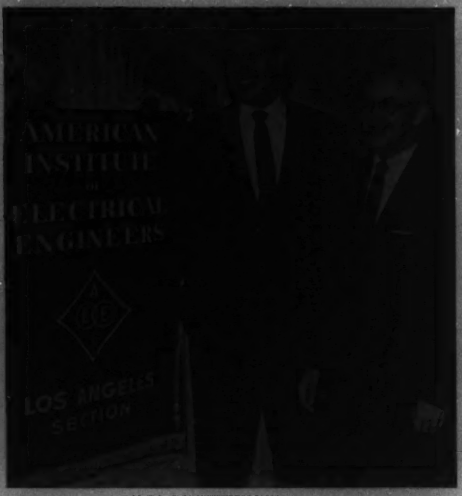
5. Develop closer liaison between college, industrial, and governmental research organizations.

6. Encourage undergraduate and graduate students who have novel, creative ideas to pursue the development of these ideas and help them to obtain financial support.

Recommendations made to scientific and engineering societies were:

1. Establish more effective practices which will increase the attendance and participation of talented young members at meetings of scientific and engineering societies.

2. Encourage the presentation and publication of philosophical papers which



ECONOMICS in engineering activity was the subject of an address by R. L. Ash (*left*), of Litton Industries at a meeting of the Los Angeles Section. Mr. Ash was introduced by H. H. Grant (*right*) of the AIEE Management Division and associate dean, School of Engineering, University of Southern California.

Rothschild

look to the future of science and technology.

3. Develop comprehensive programs for digesting research knowledge.

4. Establish society meetings to develop more effective interchange of ideas between scientists and engineers in research areas of broad mutual interest.

5. Establish free forums at engineering society conventions where any member may make a short presentation of his creative work.

6. Actively promote and encourage financial support for research.

7. Foster among society members a recognition of the contribution which they can make by stimulating the creative development of youth.

The report urged the scientific and engineering societies to take the initiative in bringing together leaders in education, industry, and Government to study the problems of large-scale research. It said, "It is imperative such studies be approached, not in the framework of preconceived ideas and the preservation of tradition, but rather with a fresh, new, and objective outlook."

North Texas Section Presents Prize Paper Awards

First, second, and third prize paper award winners in the contest for the year 1958-59 sponsored by the North Texas Section, AIEE, have been announced.

Awards were made as follows:

First Prize—Design of Steel Tower Transmission Lines for Metropolitan Areas. *O. B. Ashmore, J. A. Hunter, Jr.*, Dallas Power & Light Company.

Second Prize—Fuse Protection of High-Voltage Power Transformers. *L. A Larner, K. R. Gruesen*, Texas Electric Service Company.

Third Prize—Optimum System and Motor Protection through Proper System Grounding and Relaying. *R. W. Swarthout*, General Electric Company; *R. C. Dickson*, Phelps-Dodge.

Certificates and cash prizes were awarded the winners in the competition. The cash prizes are: $50, first prize; $30, second prize; and $20, third prize.

The certificates were presented January 19, at the North Texas Section General Meeting by J. L. Sandlin, Section chairman. Cash prizes were sent to the winners by C. B. Derrick, chairman of the Prize Awards Committee.

Accomplishments Reviewed in ECPD's 27th Annual Report

The 27th annual report of the Engineers' Council for Professional Development (ECPD), of which the AIEE is a constituent organization, reviews the accomplishments of engineers who are working for their profession to assure that it will have well-selected, well-educated, and well-oriented future members.

The continuing review of standards for engineering education in connection with the accreditation program has resulted in additional criteria being evolved.

One committee's aim is the preparation of students for a professional future with the realization of its responsibilities. A program for continued indoctrination of young engineers in the post-college period has been developed.

Subjects of study during the year have been the use of the professional title and the search for a word to identify the professional engineer properly and to avoid confusion with the nontechnical worker.

Progress is reported in the area of ethics, both in the "Principles and Practice of College Recruiting" and the proposed "Case Book on Ethics."

Reports are given from the societies on activities in the fields directly related to the ECPD committee projects.

Please mail back your membership survey card promptly.

Industry Executive Speaks on Economic Need in Engineering

R. L. Ash discussed "Economic Need and Engineering Activity" in his talk before members of the Los Angeles Section, AIEE, at the February 9 general meeting. Sponsored by the Management Division, the dinner meeting was held at the Rodger Young Auditorium in Los Angeles, Calif.

Mr. Ash, who is executive vice-president and a member of the board of directors of Litton Industries, Inc., believes that the management of any successful corporation based on engineering effort must understand the relationship between economic need and engineering activity and all its implications. He believes that the management must be able to apply this understanding successfully in guiding and directing the engineering staff.

Mr. Ash declared that although no one has yet devised a means of measuring the productivity of the engineering force in our society by weekly statistics, our private enterprise system contains within itself a virtually foolproof mechanism which continually appraises engineering accomplishment. This system responds in ways that encourage and inspire greater accomplishment while curtailing wasteful and nonproductive effort. Such a mechanism, Mr. Ash said, is the fundamental basis of the free social, economic, and political system that has made this country what it is. It is called Capitalism.

Mr. Ash suggested looking at the individual engineer, the common denominator of our engineering force, to find some clues as to the efficacy of engineering activity in the aggregate. He introduced the listeners to his book of caricatures entitled "Some Engineers I Have Known," and saying that he hoped he would not be taken too seriously, took them through his "Engineering Zoo"!

Exchange Program Inaugurated for Technical Institute Teachers

A new American–British exchange program has been inaugurated by the English-Speaking Union with the selection of two American and two British teachers for travel grants across the Atlantic. The grant holders, all on the faculties of technical institutes or colleges, will visit similar institutions in the other country. The awards, which include the cost of transatlantic and other travel plus a cost of living allowance for the 56-day period of the grant, are supported by the English-Speaking Union of the Commonwealth. The American grant holders are selected jointly by the English-Speaking Union of the United States and the American Society for Engineering Education (ASEE).

The Americans who have received grants to tour technical institutes in Great Britain during April 25-June 18, 1960, are:

J. F. Shaw, instructor, department of mechanical technology, Wentworth Institute, Boston, Mass.

J. C. Johnson, associate professor of mathematics, Northrop Institute of Technology, Inglewood, Calif.

The two British teachers coming to the United States in the Spring of 1960 for a similar tour are:

I. M. Harper, lecturer in mathematics, Loughborough College of Technology, Loughborough, Leicester.

D. W. Hopkins, head of metallurgy department, Swansea Technical College, Mount Pleasant, Swansea.

The teachers, during their 56-day stay in the United Kingdom or the United States, will visit educational institutions for an interchange of personal experience with the faculty members, students, and alumni of the schools, and the employers of the graduates.

The program was initiated by Prince Philip, Duke of Edinburgh, at the World Branches Conference of the English-Speaking Union held in Ottawa, Canada, October 30, 1958.

The plan was instituted in the United States in November 1959 when applications were invited from faculty members in programs of the technical institute type. It is being administered by the English-Speaking Unions of the Commonwealth and of the United States and by the Technical Institute Division of the ASEE through its Committee on Relations with Educational Organizations.

The American and British members of the Spring team will present summary reports on their experiences and impressions to the Technical Institute Division of the ASEE June 21, and will participate in all events of the Division during the course of its annual meeting, June 20-24, 1960, at Purdue University, Lafayette, Ind.

National Security Studied by Academy–Research Council

A committee of the National Academy of Sciences–National Research Council has declared: ". . . important national security programs, particularly those in defense, atomic energy, and space, are currently up against a materials barrier because the properties of most presently available materials are inadequate for the high-performance end-items that must withstand severe temperature, pressure, radiation, corrosion, and stress environments."

The committee declared that the lag in the development of new metals, ceramics, and plastics is holding up the development of nuclear-propulsion systems and space vehicles, as well as better missiles, rocket motors, naval vessels, and electronic devices for which theoretical designs now exist.

Author of the report is the Committee on the Scope and Conduct of Materials Research, established last Spring by Academy–Research Council President

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grade, qualifications, and fees may be obtained from Mr. N. S. Hibshman, Secretary, 33 West 39th Street, New York 18, N.Y.

D. W. Bronk to survey "the total materials research and development activities of the nation—industrial, academic, and governmental—for the purpose of identifying any critical gaps." Dr. Clyde Williams, formerly president and director of Battelle Memorial Institute was named chairman.

In transmitting the committee's report to Dr. Bronk, Dr. Williams wrote, "Considering all aspects of resources being utilized to resolve present materials problems, the committee considers that substantial inadequacies exist with respect to research programs, resources of personnel and facilities, and administrative procedures and organizations."

In its report, "More Effective Organization and Administration of Materials Research and Development for National Security," published in March by the Academy–Research Council, the committee recommends that ". . . the Government accord high priority in national security plans and programs to the science of materials and to the development of new and improved materials for national security uses, and that the relevant programs of the agencies and departments be strengthened."

"There are no magic administrative or technical solutions to the materials problem," the committee noted. "What is needed is significant strengthening at every level of activity."

The report then listed five general recommendations:

1. Greater centralization of responsibility, more support for, and more effective co-ordination of Government-sponsored materials research and development programs;

2. Government incentives to encourage research and development on new and improved materials;

3. Assurance of adequate United States supplies of every chemical element or material to support full production and use of new and improved materials;

4. Improvement and acceleration of the dissemination of research information; and

5. Strengthening of the universities in their dual role of training scientists and engineers and also of doing basic research.

Recognizing that "some efforts along the above lines are already under way in many quarters," the committee expressed the belief that "much more must be done."

The committee suggested that materials be stockpiled by the Government on the basis of potential as well as present use. The report cited tellurium and rhenium as rare metals not now on any stockpile lists whose future uses could be substantial —for thermoelectric and high-temperature applications, respectively. Tantalum, although already listed for stockpiling, may be in far greater demand than anticipated through potential usefulness in high-temperature alloys and compounds and in electronic capacitors.

Fellow Certificate Presented

Larry Kenney

ADVANCED to the grade of Fellow in the AIEE, H. L. Kertz, vice-president of the Pacific Telephone and Telegraph Company (PT&T), received his Fellow certificate from R. H. Miller, San Francisco Section chairman, at the Section general meeting March 8. Attending were *(left to right)*: L. G. FitzSimmons, chief engineer of PT&T's North California Area; Glen Ireland, vice-president—operations, PT&T; Mr. Kertz; Mr. Miller; and L. P. Cornell, first chief engineer of PT&T's new Northern Counties Area.

AIEE FELLOWS ELECTED

Board of Directors Meeting, February 5, 1960

William Herbert Bixby (AM '32, M '45), vice-president and member of the Board of Directors of the Power Equipment Company, Galion, Ohio, has been transferred to the grade of Fellow in the AIEE ". . . for contributions to automatic voltage regulated power supply." He was born December 28, 1906, at Indianapolis, Ind. He studied at the University of Michigan from which he received the B.S. degree in electrical engineering in 1930, the M.S. degree in 1931, and the Ph.D. degree in 1933. At the Chrysler Corporation, he was employed as a special problems engineer in the electrophysical laboratory, and in 1935 he was awarded the M.M.E. degree by the Chrysler Institute of Engineering. In 1936, Dr. Bixby left the corporation to join the staff of the department of electrical engineering at Wayne University where he taught both undergraduate and graduate courses in electronics as well as electricity and magnetism. He advanced to assistant professor in 1941, associate professor in 1944, and full professor in 1950. From 1945 until he left the university in 1956, he was in charge of graduate studies in the department. Concurrently with his teaching, he was active as a consultant, primarily for the Power Equipment Company of Detroit, Mich., and Galion, Ohio. In this connection, he was responsible for 18 patent applications in the field of controlled rectifiers, regulated exciters, and line voltage regulators. In 1956, he became a vice-president of the Power Equipment Company and director of its research and development activities. To facilitate further studies into the area of controlled rectification and its industrial applications, a new laboratory was built and equipped at Columbus, Ohio. Since 1950, Dr. Bixby has been a member of the Hot-Cathode Converter Subcommittee of the National Electronics Committee, of which subcommittee he is presently chairman. He is a member of the Engineering Society of Detroit, Sigma Xi, Tau Beta Pi, Phi Kappa Phi, and a Fellow of the American Association for the Advancement of Science. He has served on the AIEE Industrial Power Rectifiers Committee (1952-60) and Electronics Committee (1954-60).

Malcolm Macfarlan Bridgwater (AM '41, M '48), vice-president in charge of operations of the Arizona Public Service Company, has been transferred to the grade of Fellow in the AIEE ". . . for contributions to electric power system development and interconnected operation." He was born in Mount Juliet, Tenn., on August 7, 1896, and received the B.S. degree in engineering in 1917 from the Texas Agricultural and Mechanical College. Mr. Bridgwater was an engineer and operating superintendent of the Arkansas Power & Light Company, Pine Bluff, Ark., during 1919-21. He was assistant district manager of the Guanajuato Power & Light Company, Irapuato Gto., Mexico, in 1923-24, and operator of the Southern California Edison Company, Big Creek, Calif., in 1924. That year, he was employed as an engineer for the Arizona Power Company, a predecessor to the Arizona Public Service Company. Mr. Bridgwater was vice-president and general superintendent of the Arizona Power Company when that company became a wholly-owned subsidiary of Central Arizona Light & Power Company in 1949. He was elected vice-president and general superintendent of the subsidiary company, which was known as the Northern Arizona Light & Power Company, and held this job from 1949 until 1953 when this company was merged with the Arizona Public Service Company. He was named general superintendent of the Northern Area, and in August 1955, became superintendent of operations. In October, 1955, he was elected vice-president in charge of operations. He is a member of the Pacific Coast Electrical Association, the American Society of Mechanical Engineers, the National Society of Professional Engineers, and Tau Beta Pi. Mr. Bridgwater is a registered engineer of the State of Arizona. He is a past chairman of the Arizona Section, AIEE.

Arthur David Caskey (AM '38, M '45), assistant manager of engineering, Commonwealth Edison Company, Chicago, Ill., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to planning and design of a large power system." Mr. Caskey was born April 24, 1896, in Chicago Heights, Ill., and received the B.S. degree in electrical engineering from the University of Illinois in 1919. After a short period of plant engineering work with the Victor Chemical Works, he became a field engineer of the Public Service Company of Northern Illinois. In 1934, upon consolidation of 11 operating districts into 4 divisions, he became a division engineer at Joliet, Ill. At this time, the company instituted an extensive rural electrification program, and Mr. Caskey was instrumental in developing the engineering organization and over-all plans for the program, encompassing approximately 1,200 square miles of territory. In 1936, he was transferred to the general office in Chicago with the title of electrical engineer. When the Western United Gas and Electric Company and the Illinois Northern Utilities Company were absorbed into the Public Service Company, Mr. Caskey was responsible for the planning and design of all major components of the entire system, including new generating stations, substations, and large customer service stations. At the time of the consolidations of the Public Service Company with the Commonwealth Edison Company in 1953, he continued as electrical engineer with added responsibilities, particularly in the transmission and distribution areas of engineering. In 1957, he was appointed assistant manager of engineering. He was a member of the Edison Electric Institute Transmission and Distribution Committee, the Association of Edison Illuminating Companies' Switching and Switchgear Committee, and is currently a member of the association's Power Distribution Committee. Mr. Caskey is a registered professional engineer in the State of Illinois, a member of Tau Beta Pi and Eta Kappa Nu. He has served on the AIEE Power Generation Committee (1943-52) and on the Executive Committee of the Chicago Section, AIEE.

Theodore Ritson Halman (AM '36, M '43), superintendent of electrical system performance, The Detroit Edison Company, Detroit, Mich., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to protective relaying for electrical system performance." Mr. Halman was born May 7, 1898, in Oshawa,

W. H. Bixby

Gene of Phoenix

M. M. Bridgwater

A. D. Caskey

T. R. Halman

F. K. Harris

Michigan University

L. N. Holland

Moulin Studio

H. L. Kertz

Ont., Canada. He graduated from the University of Michigan in 1922 with the B.S. degree in electrical engineering. Upon graduation, he was employed by the Detroit Edison Company as an assistant testing engineer in the electrical operating department. In 1928, he became relay engineer, responsible for the relay engineering of the power plants, substation, transmission, and distribution systems. He also was responsible for the field checking and testing of all relays and associated control wiring. During 1935-45, he was in charge of the distribution of the system load between the various power plants to insure compliance with the "loose-linked" concept in effect at that time. In 1945, he was promoted to supervising engineer in charge of testing and relaying in the electrical system department. He was placed in charge of the General Test Division, which covered engineering studies and field testing of all electric apparatus other than relays, and the Cable Corrosion and Loading Division, which covered the protection of the cable system against damage from electrolysis or chemical corrosion or overloading. In 1952, he was appointed superintendent of engineering, testing, and relaying in the Apparatus, Cable, and Relay Divisions. He was advanced to his present position of superintendent of electrical system performance in 1954, and has been responsible for the operation of the entire system. He was a member of the National Fuel Efficiency Program and is a registered professional engineer in the State of Michigan. Mr. Halman has served on the AIEE Relays Committee (1947-56).

Forest Klaire Harris (AM '42, M '47), physicist in the Electricity and Electronics Division of the National Bureau of Standards, Washington, D. C., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to the art of electrical instrumentation." He was born August 26, 1902, in Gibson County, Ind., and was educated at Oklahoma and Johns Hopkins Universities. His Ph.D. degree is from Johns Hopkins. He has been associated with the National Bureau of Standards during his entire professional career, as a research associate during 1923-25, and since that time as a staff member. Dr. Harris has been on the teaching staff of George Washington University since 1941 and is now professional lecturer in electrical engineering at George Washington University. In 1925, he became a permanent employee in the Electrical Instruments Section of the Electricity Division, National Bureau of Standards, and has advanced steadily through the various civil grades to his present assignment as alternate chief of the Electrical Instruments Section. During World War II, he was first assigned to a project on lightning hazards to aircraft and later was placed in charge of a gyroscope group working on an automatic bomb director problem. He was shifted during the Korean hostilities to help engineer special mine fuses. As alternate chief, he now supervises the Electrical Instruments Section's research, development, and engineering work incidental to better measurement and dissemination of electrical units and standards. In 1955, he received the Department of Commerce Meritorious Service Award for meritorious accomplishments and authorship in the field of electrical measurements. His work has been principally in the area of electrical measurements, and he has been concerned with the developments of standards and methods of precise measurement in the d-c and low-frequency field. He is a member of the Washington Academy of Sciences, Phi Beta Kappa, Sigma Tau, and Sigma Xi. He is a member of the American Standards Association Committee C-12 for the Code on Electricity Meters and Committee C-39 on Indicating Instruments. He has served on the following AIEE Committees: Basic Sciences (1947-52), Instruments and Measurements (1951-56), Indicating and Integrating Instruments (1956-60, chairman 1957-59), Instrumentation Division (1957-60), and Special Instruments and Auxiliary Apparatus (1958-60).

Lewis Nelson Holland (M '43), professor of electrical engineering, University of Michigan, Ann Arbor, Mich., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to electrical engineering curricula, especially the incorporation of uhf (ultra high frequency) pedagogy." Prof. Holland was born December 20, 1900, in Jackson, Mich. He received his B.S. and M.S. degrees in 1923 and 1926, respectively, from the University of Michigan, and has taught there for the last 36 years, in succession, as instructor, assistant professor, associate professor, and professor. During World War II, he took an active part in establishing courses in uhf techniques. In 1941, when the demand for trained specialists in electronics and uhf techniques exceeded the country's capacity to supply them, the U. S. Office of Education through the Engineering, Science, and Management Defense Training Division established a training program with 40 co-operating institutions. Prof. Holland attended the teachers' conferences on uhf techniques associated with this training program. He participated in the preparation of the syllabus for courses in uhf techniques and organized the uhf courses based on the syllabus. He also gave instruction in this subject. He served from time to time during 1942-43 as special consultant to the Navy Department in the preparation of the Navy V-12 Curricular Schedules and Course Descriptions. He has been responsibile for many of the innovations that have been introduced into the electrical engineering curriculum at the University of Michigan. He was chairman of the Engineering College Curriculum Committee during its first 5 years and continues to serve on the Senate Advisory Committee, the Subcommittee on Campus Planning, the Subcommittee on Research, the Freshman Program Committee, the Electronic Defense Group Steering Committee, and the Electronic Physics Laboratory Advisory Committee. He is chairman of the Electrical Engineering Curriculum Management Committee, and is the graduate student advisor for electrical engineering. Prof. Holland is a Fellow of the American Association for the Advancement of Science, a Fellow of the Institute of Radio Engineers, and a member of the American Society for Engineering Education, the Engineering Society of Detroit, Eta Kappu Nu, and Tau Beta Pi. He is a registered professional engineer of the State of Michigan.

Hubert Leonard Kertz (M '48), vice-president in charge of the operating staff departments, Pacific Telephone and Telegraph Company, San Francisco, Calif., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to the design, construction, and administration of a large and complex communication network." He was born July 11, 1910, in San Francisco, Calif. In 1934, he received the B.A. degree in electrical engineering from Stanford University, and in 1936, the graduate degree in electrical engineering. During 1937-42, he was employed as an engineer for the Pacific Telephone and Telegraph Company. His work involved maintenance engineering. He served in the U. S. Navy as a lieutenant commander in the South Pacific Area during 1942-46. His duties were communications and radio radar maintenance. He was awarded the bronze star decoration for meritorious service in the fleet and is now a retired commander of the U. S. Navy Reserve. In 1946, Mr. Kertz returned to the company as an equipment maintenance engineer. He became central office equipment engineer in 1947, general studies engineer in 1948, and equipment and building engineer in 1952. The following year, Mr. Kertz was named assistant vice-president in charge of all engineering activities for the company. During the period 1953-58, the phenomenal growth in the Pacific Coast states required expansion of telephone plant facilities. Mr. Kertz was in complete charge of the engineering

Skelton

J. V. Kresser

W. C. Lallier

R. M. Milton

C. V. Morey

staff co-ordination, advisory and policy functions for the entire engineering effort in planning and constructing this expansion of telephone plant. In 1958, he was named to his present position as vice-president. In addition to engineering, he now has the responsibility of supervising all plant, traffic, and commercial operations for the company.

Jean Victor Kresser (AM '32, M '43), senior engineer, Pacific Coast Region Engineering and Service, Westinghouse Electric Corporation, San Francisco, Calif., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to the design, control, and literature of electric power apparatus." Mr. Kresser was born September 26, 1904, in Noumea, New Caledonia. He graduated from the Massachusetts Institute of Technology in 1930 with the B.S. degree in electrical engineering and was employed by Westinghouse at East Pittsburgh, Pa. He spent the first 10 months on the company's graduate student course, including Design School, and then became an engineer, assisting in theoretical and field investigations of lightning phenomena, application of the method of symmetrical components, and solution of problems in systems engineering. During 1932-36, he was a design engineer for Electrolift Corporation of San Francisco. The following year, he was employed by Standard Oil Company of California, first in San Francisco, and then in Richmond, Calif., as an electrical designer. In 1937, he rejoined the Westinghouse organization as a district engineer in its San Francisco office. He became senior engineer in 1949, with his main assignment in the electric utility industry. He remained as consultant in special applications or problems in the industrial field and also was made consultant on special problems for the Westinghouse Pacific Coast Region. In 1953, Mr. Kresser became a member of the Westinghouse Pacific Coast Region staff, retaining the title of senior engineer. He was assigned region-wide responsibility as consultant on all major projects, on system engineering, and planning on engineering problems. He is a member of the Pacific Coast Electrical Association and of the Northwest Electric Light and Power Association. He has served on the following AIEE Committees: Carrier Current (1951-54), Electronic Power Converters (1953-54), Nucleonics (1954-60), and Nucleonic and Radiation Instruments (1957-60).

Wesley Charles Lallier (AM '31, M '41), transmission and outside plant engineer, Wisconsin Telephone Company, Milwaukee, Wis., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to engineering of a statewide communication system." Born July 6, 1900, in Denison, Texas, he received the B.S. degree in electrical engineering in 1922 from the University of Wisconsin. After graduation, he joined the Wisconsin Telephone Company as a transmission engineer. In 1927, he was transferred to the operations and engineering department of the American Telephone and Telegraph Company, New York, N. Y., where he worked in the plant engineering group on voice frequency and carrier telephone systems. In 1928, he returned to the Wisconsin Telephone Company and, subsequently, became the transmission and protection engineer. His duties involved establishment of standards of transmission and protection for exchange, toll, and special service facilities, design of major trunk and toll cables, establishment of carrier systems, co-ordination of power and communication systems, and supervision of large additions to the telephone network in the State of Wisconsin. In 1946, he was appointed plant extension engineer and was made responsible for long range construction plans, programming for additional central office switching centers, and preparation of the construction budget. In 1949, he was appointed engineer of outside plant and, subsequently, in 1955 became the engineer of transmission and outside plant with responsibility for supervision of engineering functions associated with wire, radio, microwave, and other means of transmission, outside plant engineering, and the engineering aspects of data transmission. Mr. Lallier is a member of the National Society of Professional Engineers and a past president of the Milwaukee Chapter, Wisconsin Society of Professional Engineers. He is a member of the Engineers' Society of Milwaukee and past chairman of the Functional Section Committee for Industry, Wisconsin Society of Professional Engineers. He is a registered professional engineer of the State of Wisconsin.

Robert McCarley Milton (AM '25, M '32), chief of Electrical Engineering and Design Branch of the Division of Power Planning and Engineering, Tennessee Valley Authority, Chattanooga, Tenn., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to design of high-voltage substation, switchgear, and heavy-current buses." Mr. Milton was born September 22, 1901, in Baldwyn, Miss., and was educated at Mississippi State University. During 1923-27, he was a junior engineer in the U. S. Engineers Office. He assisted with the installation of the electric equipment at the Wilson Dam hydroelectric project. In 1927-31, he was employed by Allied Engineers of Birmingham, Ala., as an electrical engineer, and was engaged in the design of high-voltage substations for the Commonwealth and Southern Company. He returned to the U. S. Engineers in 1931 and was assigned to the New Orleans, La., district, where he was responsible for the design of electric equipment involved in the locks, movable bridges, and generating plans associated with the Intra-Costal Canal between New Orleans and the Texas state line. Since 1933, he has been employed continuously by the Tennessee Valley Authority. His first assignment with this company was as a design engineer on transmission lines and substations. He advanced through a succession of design positions in the Division of Power Engineering and Construction. In 1950, he assumed his present position with responsibility chiefly for general problems involved in substations supplied by a stiff system having heavy fault currents. He is a member of Phi Kappa Phi, and has served on the American Standards Association Power Circuit Breaker Committee. Mr. Milton is a member of the AIEE Switchgear Committee (1955-60).

Charles Vincent Morey (AM '30, M '40), meter engineer, electrical engineering department, Consolidated Edison Company of New York, Inc., New York, N. Y., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to the art and practice of electric power metering." Mr. Morey was born September 28, 1903, in Fall River, Mass., and graduated in 1925 from the Worcester Polytechnic Institute with the B.S. degree in electrical engineering. That year, he was employed by the United Electric Light and Power Company, one of the companies later merged to form Consolidated Edison. With the exception of a period during 1943-46 when he held various supervisory positions in the production and distribution departments in connection with the company's Executive Development Program, his time has been devoted to elec-

tric and gas metering and meter engineering. In 1930, he was made supervisor of the Meter Bureau of United Electric, and when the operations of this company were merged with the New York Edison Company in 1933 he was appointed assistant to the superintendent of the Meter Bureau for both companies. At the formation of Consolidated Edison, he was made assistant meter engineer and remained in this position during 1937-43 and 1946-51, until he became meter engineer in 1951. As meter engineer, he is responsible for the preparation of all procedures and specifications for the acceptance, testing, installation, and maintenance of the company's watthour meters, gas meters, steam meters, and associated equipment. Mr. Morey is a registered professional engineer of the State of New York. He is a past chairman of the Edison Electric Institute Meter and Service Committee and of the New York State Electric Meter Engineers Committee. He is a member of the Association of Edison Illuminating Companies, the National Electrical Manufacturers Association, the American Standards Association, the International Association of Electrical Inspectors, the American Gas Association, and the Edison Engineering Society. Mr. Morey has served on the AIEE Instruments and Measurements Committee (1939-42) and Indicating and Integrating Instruments Committee (1959-60).

Robert Francis Munier (AM '32, M '45), advanced design engineer in the Motor Product Division, Wagner Electric Corporation, St. Louis, Mo., has been transferred to the grade of Fellow in the AIEE, ". . . for contributions to the thermal performance of motors, particularly in enclosed forms and small ratings." Born in O'Fallon, Ill., on November 14, 1906, he was educated at Washington University, St. Louis, Mo., from which he received the B.S. degree in 1928 and the M.S. degree in 1930, both in electrical engineering. Mr. Munier held the Century Electric Research Fellowship and served as assistant instructor in engineering courses while working on his master's degree. He was employed by Wagner Electric Corporation in 1930 as an electrical engineer in the New Design and Development Section, from which he transferred in 1932 to the Small Motor Engineering Section. In 1934, he joined the Emerson Electric Manufacturing Company of St. Louis as an electrical engineer in the Production Engineering Division. In 1941, he was appointed chief motor engineer for Emerson. As a division head, he was responsible for the design, development, sales co-ordination, factory co-ordination, and testing procedures of all ratings and sizes of general purpose, special purpose, definite purpose, and hermetic types of standard motors. During World War II, Mr. Munier designed and developel a complete line of direct-current motors for military aircraft service and handled customer engineering work for these motors. He was responsible for air conditioner and power tool engineering. In 1955, he was named consulting engineer for the company, at which he headed lamination design and performance computing work. With the Wagner Electric Corporation since 1958, Mr. Munier has concentrated on integral hp hermetic motor design and development with much emphasis on part-winding starting problems. Since 1952, Mr. Munier has taught evening courses of the graduate school of St. Louis University Institute of Technology. During World War II, he served as an industry representative on the Industry-Air Force Standardization Group for aircraft rotating electric equipment. He has been an industry representative on Underwriters' Laboratories joint committees with industry and liaison with Canadian Standards Association. Mr. Munier has served on the AIEE Rotating Machinery Committee (1951-60).

Robert Raymond Peatfield (AM '37, M '46), assistant chief electrical engineer, Stone & Webster Engineering Corporation, Boston, Mass., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to co-ordinated design of thermal and hydraulic generation." Mr. Peatfield was born November 1, 1906, in Dorchester, Mass., and received the B.S. degree in electrical engineering from the Massachusetts Institute of Technology in 1928. Immediately after graduation, he joined the test department of the New York Edison Company. He was associated with the Consolidated Edison Company of New York, Inc., and its predecessor companies in the capacity of tester, general tester, junior engineer, assistant engineer, and finally superintendent's assistant until 1943. For 15 years, the work included electrical distribution engineering, electrical distribution operation, and gas production. In 1943, he joined the Tennessee Eastman Corporation at Oak Ridge, Tenn., and became managing engineer, then superintendent of the electrical operating and engineering departments in the Y-12 Area of the Manhattan Engineer District. In 1946, he joined the Electrical Division of Stone & Webster and has been responsible for the electrical engineering portion of many thermal and hydroelectric power plants, as well as transmission lines and substations. He engineered and put in service the first of the highest voltage 154-kv transmission lines in Turkey in 1952. He was in charge of the electrical engineering portion of the facilities for the 30-bev (billion electron volt) alternating gradient proton synchrotron now being built at Brookhaven National Laboratory. Since 1946, he and his associates have designed and engineered the electrical features of steam power plants with a capability of 7,130 mw and hydroelectric plants rated 470 mw now in operation. They are currently designing plants totaling 3,200-mw thermal and 770-mw hydro for future operation. He is a registered professional engineer of the States of New York and Massachusetts, and is a member of the Electrical Equipment and System Committee of the Edison Electric Institute. Mr. Peatfield has served on the AIEE Power Generation Committee (1957-60).

Frank Crofford Rushing (M '45), manager of the motor engineering department, Westinghouse Electric Corporation, Buffalo, N. Y., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to dynamic balancing of rotating electrical apparatus." Mr. Rushing was born July 11, 1906, in Nordheim, Texas. In 1928, he graduated from the University of Texas with the B.S. degree in mechanical engineering. He was employed on the graduate student course of Westinghouse Electric Corporation from which he was selected for special training in advanced design involving studies at the University of Michigan and the University of Pittsburgh, where he received the M.S. degree in 1930. Mr. Rushing worked for Westinghouse as an electric motor designer for 2 years. He then was awarded the B. G. Lamme Memorial Scholarship and studied at the University of Charlottenberg, Germany, in the field of electric machine design. He returned to the Westinghouse Research Laboratories to an assignment in the advanced mechanics department. There, he developed high-speed motor drives for rayon spinners, and did dynamic balancing including both factory and field balancing equipment and methods. Mr. Rushing did original work on shock testing and shockproof design for electric equipment for Navy usage. He also developed an ultra-high-speed centrifuge for uranium isotope separation. In 1945, he became manager of a-c motor engineering for Westinghouse, and in 1946, manager of the motor engineering department. He is a registered professional engineer of the State of New York, and a member of the American Society of Mechanical Engineers, Tau Beta Pi, and Sigma Xi. He received the Westinghouse Order of Merit for analysis, invention, and design in the field of dynamics. He was awarded the U. S. Navy Certificate of Commendation for service to the Navy in World War II,

Todd Studio

R. F. Munier

Fasch Studio

R. R. Peatfield

Towne Studio

F. C. Rushing

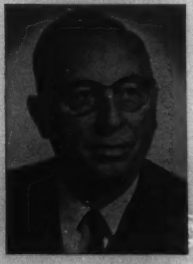
and the Office of Scientific Research and Development Certificate of Appreciation for service during World War II on an atomic project. He has served on the AIEE Rotating Machinery Committee (1947-60).

Robert Charles Siegel (M '42), chief engineer, Wisconsin Telephone Company, Milwaukee, Wis., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to direction of expansion of a state-wide communication system." Born January 18, 1898, in Los Angeles, Calif., Mr. Siegel received his B.S. degree in electrical engineering from the University of Wisconsin. After graduation in 1921, he joined the Wisconsin Telephone Company as an engineer of transmission and protection. In this work, he was active in the program of establishing, testing, and maintaining long-distance telephone circuits. In 1923, he was advanced to the position of toll fundamental plan engineer, in which capacity he supervised the preparation of long term plans to meet economically requirements for future long-distance telephone service. He became plant extension engineer in 1928, heading a section which determined types and amounts of plant and equipment needed to meet future requirements for telephone service throughout the company's operating area. During the early 1930's, he had charge of a state-wide company rate case study for outside plant including appraisals, existing depreciation, and plant separations. In 1946, he was appointed chief engineer with responsibility for directing the engineering activities associated with the largest program of expansion and service improvement undertaken in the history of the company. Mr. Siegel is a member of the National Society of Professional Engineers, the Wisconsin Society of Professional Engineers, the Engineering Society of Milwaukee, and the Armed Forces Communications and Electronics Association. In 1954, he was cited by the College of Engineering, University of Wisconsin, for outstanding accomplishment in the field of telephone engineering. He is a member of Tau Beta Pi.

Nicholas Stadtfeld, Jr. (M '45), electric utility engineer with the Westinghouse Electric Corporation, Boston, Mass., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to application of the principle of power system protection and control." He was born December 2, 1907, in New York, N. Y., and studied at the College of the City of New York from which he received the B.S. degree in 1929 and the electrical engineering degree in 1930. He was employed by the Consolidated Edison Company, New York, during 1930-41, in the test department, Outside Plant Bureau, and service inspection department. He spent the next 4 years in U. S. Government service at the Panama Canal Office engineering department, Balboa. He was the electrical engineer in responsible charge of a wide variety of work including supervisory control systems, frequency changeover installations, power distribution systems, and installations of switchgear and generating equipment in a naval shore station. Since 1945, he has been associated with the Westinghouse Electric Corporation in the Boston office. As consulting and application engineer, he serves as consultant to electric utility companies, consulting engineers, industrial concerns, and municipalities on problems of system planning, short-circuit studies, load flow studies, and application of protective relays. He is a frequent lecturer on surge protection of stationary and rotating equipment, symmetrical components, and application of protective relays to utility and industrial power systems. At the Boston Section, AIEE, he is chairman of the Section and Institute Affairs Committee, chairman of the General Meetings Committee, vice-chairman of the Member Gifts Campaign Committee, and a member of the Executive Committee. He has served on the AIEE Protective Devices Committee (1953-54).

Julius C. Strasbourger (AM '31, M '40), executive vice-president of Muncie Engineering, Inc., Muncie, Ind., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to mechanization of electric utility system construction and maintenance." He was born December 22, 1906, in Cleveland, Ohio, and attended the University of Cincinnati from which he received the electrical engineering degree in 1929. During 1925-29, he was employed by the Union Gas & Electric Company, Cincinnati, Ohio, on electrical maintenance and construction. In 1929, he went to the Cleveland Electric Illuminating Company, Cleveland, Ohio, as an electrical engineer. The following year, he was assigned to field engineering for the company. Mr. Strasbourger was assigned to system operation in 1934. In 1939, he became supervising engineer of the Office and Technical Section and electrical department. He worked on special assignments during 1947-53, which included development of job specifications for a 1,700-man bargaining unit, co-ordination of a $130-million construction program, and direction of a special activities group handling allotments and allocations. He also initiated a program of mechanization of electric utility field operations which developed into a country-wide activity. In 1953, he became general supervisor in charge of mechanical buying and contracting. In 1958, he became executive vice-president of Muncie Engineering, Inc., Mitchell Maintenance Company, and Lift-a-Loft Company, of Muncie, Ind. Mr. Strasbourger is a registered electrical engineer of the State of Ohio and a registered professional engineer of the State of Indiana. He is a member of Eta Kappa Nu, the Cleveland Engineering Society, and the Cleveland Technical Societies Council. He has served as AIEE District 2 vice-president (1953-55), District 11 vice-president (1956-57), director (1956-61), and has been a member of the following AIEE Committees: Planning and Co-ordination (1946-49, 1954-57, 1959-60); Sections (1947-55, chairman 1947-49); Award of Institute Prizes (1948-49); Safety (1950-51); Administration Department (chairman 1956-57); Executive (1957-58); Finance (1957-58); and was AIEE representative to the Engineers Joint Council (1957-58).

Arthur Charles Sugden (AM '34, M '45), manager of engineering, Long Island Lighting Company, Hicksville, N. Y., has been transferred to the grade of Fellow in the AIEE ". . . for contributions in the field of power transmission and distribution." Mr. Sugden was born February 11, 1908, in Wilkes Barre, Pa., and in 1930 received the B.S. degree in electrical engineering from Pennsylvania State College where he was awarded the J. C. White graduate fellowship. He received the M.S. degree in electrical engineering from the Massachusetts Institute of Technology in 1931. Mr. Sugden began his career with the General Electric Company, Schenectady, N. Y., in 1931 and completed the company test course and advanced course in engineering. During 1935-37, he was engaged in lightning research at the General Electric Pittsfield, Mass., High-Voltage Laboratories. In 1937-43, he was with the Central Station Division, New York Office of General Electric, where he specialized in transmission distribution and relaying



R. C. Siegel

Lenscraft Photo

Nicholas Stadtfeld, Jr.

J. C. Strasbourger

A. C. Sugden

Romaine Studio

A. J. Swank

H. R. Wall

Elson-Alexandre

C. A. Wells

work. During World War II, he was assistant chief electrical engineer of the Diffusion Project of the Manhattan Project. In 1945-47, he dealt with transmission and substation problems of local utilities in his capacity of application engineer in the Central Station Division, New York Office of General Electric. Mr. Sugden started work for the Long Island Lighting Company in 1947 as electric planning engineer. He was made assistant engineering manager in 1950 and was appointed engineering manager in 1958. He has been closely associated with the planning, development, and design of the postwar transmission, substation, and generation programs of the Long Island Lighting Company. In addition to his duties as engineering manager, Mr. Sugden directs the activities of the Atomic Energy Division of the company. He is a member of Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi, the American Nuclear Society, the Nuclear Engineering Division of the American Chemical Society, and is a registered professional engineer in the State of New York. He has served as treasurer, secretary, vice-chairman, and chairman of the Power and Industrial Division of the New York Section, AIEE, and was also a member of the Executive Committee of the New York Section.

Arthur J. Swank (M '43), vice-president in charge of electric operations, Pacific Gas and Electric Company (PG&E), San Francisco, Calif., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to construction and operation of a large power system." Mr. Swank was born in Colusa, Calif., September 28, 1896, and is a 1918 graduate of the University of California, cum laude in electrical engineering. Before graduation, Mr. Swank was a teaching fellow in the university's physics department. Mr. Swank had worked as a laborer at various PG&E powerhouses and substations during college summer vacations, and after service in the U. S. Army he started regular employment with the company in 1919 at the Folsom Powerhouse. He was promoted successively to electrician and foreman. By 1922, he was an assistant engineer in the general construction department and served as a construction superintendent during 1924-33. During this period, Mr. Swank initiated and developed testing techniques and programs for the start-up of steam and hydroelectric generating plants, transmission, distribution, and converter stations and their various components constructed under his supervision. In 1933-36, after the PG&E system was enlarged through merger with the Great Western Power Company and the San Joaquin Light and Power Company, Mr. Swank served as a load dispatcher. Returning to the general construction department, he became an assistant engineer of station construction in 1937 when PG&E was expanding its electric system. In 1945, Mr. Swank was named engineer of station construction as PG&E began its greatest decade of growth during which electric generation capacity was tripled, from more than 1.6 million kw in 1945 to more than 4.3 million kw at the end of 1955. The present capacity is more than 5.2 million kw. Mr. Swank became assistant manager of general construction in 1950 and manager in 1951 as the expansion program was going ahead at full speed; 2½ years later, he was elected vice-president in charge of this department. Mr. Swank was a director of the Engineers Club of San Francisco, has been a director of the Pacific Coast Electrical Association, and is an associate member of the Associated General Contractors of America, Inc.

Harry Rutherford Wall (AM '39, M '45), vice-president—electric operations, Consumers Power Company, Jackson, Mich., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to development and operation of a large utility system." Mr. Wall was born July 24, 1909, in Shreveport, La., and graduated from the Carnegie Institute of Technology in 1931 with the B.S. degree in electrical engineering. During 1933-37, he was employed by the Cleveland Electric Illuminating Company, Ashtabula, Ohio, as electric power station operator and draftsman for the operating superintendent. In 1937-39, he was an electric control designer and draftsman for the Tennessee Electric Power Company, Chattanooga, Tenn. He was associated with the Commonwealth & Southern Corporation, Jackson, Mich., during 1939-42, as an engineer assigned to power station electrical control design and technical studies and investigations. On military leave of absence during 1942-45, he first prepared for service as a radar officer by successfully completing the pre-radar course at Harvard University, and the advanced radar course at the Massachusetts Institute of Technology, where he also studied in the Radiation Laboratory. He served 2 years as the officer-in-charge of radar at the U. S. Naval Dry Dock, South Boston, Mass., and was responsible for planning, installation, servicing, testing, and alteration of shipborne search radar on all types of naval combat and auxiliary vessels. He returned to Commonwealth and Southern in 1945 as an engineer in the Technical and Investigations Section. In 1946, he advanced to senior engineer. After 1949, the corporation's name was changed to Commonwealth Associates Inc., and he became principal engineer, a position he held until 1951 when he was advanced to head engineer. That year, he went to Consumers Power Company as assistant general supervisor of electric production and transmission. In 1952, he became general supervisor of electric production and transmission, and in 1954, vice-president in charge of electric production and transmission. He assumed his present position of vice-president in charge of electric operations in 1958. He is a member of the Association of Edison Illuminating Companies' Power Generation Committee, the National Society of Professional Engineers, the American Management Association, Eta Kappa Nu, and Theta Tau. He is a member of the Executive Committee, Industrial Safety Advisory Council of Michigan, and is a past president and present director of the Michigan Safety Conference. He served on the AIEE System Engineering Committee (1951-53).

Clarence Amos Wells (AM '37, M '48), transmission and protection engineer, Pacific Telephone and Telegraph Company, Los Angeles, Calif., has been transferred to the grade of Fellow in the AIEE ". . . for technical and educational contributions in the field of communication transmission engineering." Mr. Wells was born February 5, 1895, in New Haven, Conn., and studied at Occidental College. He went to work for the Southern California Telephone Company in Los Angeles in 1917. Until 1920, he was engaged in engineering of the telephone outside plant and its protection and inductive and structural co-ordination with power systems. In 1920, he became a transmission engineer. After attending a full time school on the technical phases of telephone transmission conducted by the Pacific Telephone and Telegraph Company in San Francisco, Mr. Wells became transmission supervisor, in charge of a group of engineers responsible for transmission design of telephone plant in Southern California. In 1924, he was made exchange transmission engineer in the newly formed chief engineer's office at Los Angeles in charge of a group responsible for design of all exchange telephone plant in that area. In 1937, he became transmission and protection engineer for the Southern California Telephone Company, which became an operating area of the Pacific Telephone and Telegraph Company in 1947. This position involved responsibility for transmission design and electrical protection including inductive interference on all of the Pacific Company's communication systems in Southern California. His work has included development in recent years of an engineering education program in the Pacific Company and substantial contributions to the engi-

PG&E Photo

C. C. Whelchel, Jr.

W. S. Wilder

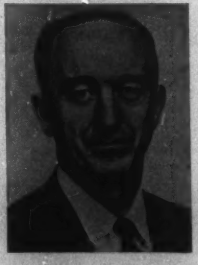
neering education program now being developed throughout the communications industry. He is a senior member of the Institute of Radio Engineers, a member of Phi Beta Kappa, Eta Kappa Nu, and the Engineering Advisory Committee for the State of California's College at Los Angeles. Mr. Wells is a past chairman of the Los Angeles Section, AIEE, and has served on the following AIEE Committees: Radio Communications Systems (1954-60), Surveys (1957-58), Student Branches (1958-60), Communication Division (1959-60), and District 8 representative of the Technical Operations Department (1958-60).

Cornelius Cooper Whelchel, Jr. (M '30), chief mechanical engineer, Pacific Gas and Electric Company (PG&E), San Francisco, Calif., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to design of large steam turbines and power plants and evolution of practical nuclear generation." Mr. Whelchel was born September 2, 1900, in Comer, Ga., and received the B.S. degree in electrical engineering in 1921 from the Georgia Institute of Technology. He was a student engineer on both Westinghouse and General Electric test courses and spent 6 months in telephone engineering with Western Electric in Chicago, Ill. During 1923-30, he was first a construction and then a central station application engineer with the General Electrical Company, Schenectady, N. Y., except for a 6-month loan in 1928 to the Georgia Power Company. He made a detailed study of Passamaquoddy tidal power and its transmission to load areas. In 1930-31, he was loaned to Saltos Del Duero, Spain, as consulting electrical engineer for a new hydroelectric system, including the generating plant and its associated 161-kv transmission and low-voltage distribution system. In 1931, he resumed work at Schenectady on hydroelectric projects, transmission line studies, and utility system planning. In 1939, he became assistant chief mechanical engineer, and during 1941-47 was chief mechanical engineer for Niagara Mohawk at Buffalo, N. Y., in charge of steam power plant design and construction. Since 1947, as chief mechanical engineer for PG&E, he has been engaged in that company's postwar power building program which has completed, or has under construction, approximately 3.5 million kw of new steam capacity, including power from geothermal steam at the Geysers and two atomic plants. He is a member of the Operating Committee of the Nuclear Power Group in Chicago, Ill., and participated in the studies and investigations which resulted in the decision to build the 180-mw Dresden Nuclear Power Station. Since 1951, he has directed PG&E's nuclear power feasibility studies and is now actively engaged in the company's nuclear power program. Mr. Whelchel is a member of the American Society of Mechanical Engineers, the Association of Edison Illuminating Companies' Committee on Power Generation and chairman of the association's Subcommittee on Power Station Auxiliaries, and a charter member of the American Nuclear Society. He served on the AIEE Power Generation Committee (1949-50, 1953-59).

Willard Smith Wilder (AM '49), electrical engineer, Wisconsin Electric Power Company, Milwaukee, Wis., has been transferred to the grade of Fellow in the AIEE ". . . for contributions to direction of design of power plants, transmission, and distribution." Born February 5, 1896, in Ashland, Wis., he attended the University of Wisconsin from which he received the B.S. degree in 1918 and the electrical engineering degree in 1921. Since 1919, Mr. Wilder has served in various capacities with the Wisconsin Electric Power Company, starting in the Meter and Testing Division as assistant to the superintendent. During 1923-48, he was technical assistant to the chief electrical engineer. His duties included special investigations which involved all phases of radio communications rebuilding of an extensive private telephone system, and the adoption of a carrier current communications system together with fixed and mobile radios. He performed the basic research and design for the company's first 250-mile 138-kv transmission system, and subsequently was responsible for the introduction of a supplementary 230-kv transmission system with associated power plant and substation equipment to co-ordinate these two high-voltage transmission systems. For 11 years, he has been manager of the company's electrical engineering organization of approximately 150 employees. His responsibilities include the direction of planning, development, and design of electrical facilities in power plants and substations and the associated transmission and distribution systems to keep pace with load growth in the utility's 12,000-square-mile operating area in eastern Wisconsin and upper Michigan. He is a member of the Management Committee of the University of Wisconsin A-C Calculator Board and previously served in a similar capacity at the Illinois Institute of Technology. He is a life member of the Wisconsin Utilities Association and is a member of the Wisconsin State Electrical Code Committee, the Great Lakes Utilities Radio Committee, and the Engineers' Society of Milwaukee. He is a registered engineer in the State of Wisconsin.

AIEE PERSONALITIES

C. E. Applegate (AM '49, M '56) has been appointed staff specialist—new products of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., Waltham, Mass. Mr. Applegate previously was a member of the senior engineering staff of Arthur D. Little, Inc.



C. E. Asbury

C. E. Asbury (AM '39, M '46) was recently appointed chief electrical engineer of Commonwealth Associates Inc., Jackson, Mich. He had been supervisor of the Electrical Application Section in the electrical engineering department. Mr. Asbury has served on the AIEE Switchgear Committee (1952-60) and Standards Committee (1959-60).

L. A. Backer (M '46) has been named executive vice-president of Thermal Controls, Inc., and O.K. Electronics of Nutley, N. J., in charge of the company's entire operation from design to final delivery.

J. M. Barnes (AM '54) has been appointed systems design engineer for 2-way radio equipment of the General Electric Company's communication products department, Lynchburg, Va.

N. A. Begovich (AM '44) has been named assistant manager of Hughes Aircraft Company's ground systems group, Fuller-

ton, Calif. He will serve also as director of product line operations. Dr. Begovich was formerly director of engineering at the Hughes plant.

K. G. Bengston (AM '59) has been assigned as application engineer in the industrial systems department of the General Products Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

C. R. Billman (AM '53) has been appointed general manager of the National Electric Division, H. K. Porter Company, Inc., Pittsburgh, Pa. Mr. Billman was most recently assistant to the president of Porter.

Carl Boyers, Jr. (AM '54) has been appointed by Minneapolis-Honeywell Regulator Company as chief engineer of its Rubicon Instruments Division in Philadelphia, Pa.

J. H. Burnett (AM '34, M '52), former vice-president of sales for Electrons, Inc., Newark, N. J., has been appointed marketing manager for the F. L. Moseley Company of Pasadena, Calif.

Stan Burns (AM '47) has been named director of engineering, American Electronics, Inc., Ground Support Division, El Monte, Calif. He was formerly with Marathon Electric Manufacturing Corporation, Wausau, Wis.

F. P. Caruthers (M '59), project engineer of Specialties, Inc., Syosset, N. Y., has been named voting representative for the corporation in the National Electrical Manufacturers Association.

B. F. Cassidy (AM '53) has been named manager, D1G power plant engineering–electrical in the nuclear destroyer project (D1G) at the Knolls Atomic Laboratory, operated by the General Electric Company, Schenectady, N. Y., for the Atomic Energy Commission.

N. B. Cawthorne (M '59) has been appointed technical director of L. Frank Markel & Sons, Norristown, Pa. He was formerly director of that company's High Temperature Insulation Division.

J. D. Confeld (M '58) has been appointed product analyst in Stromberg-Carlson's Telecommunication Division, Rochester, N. Y. Prior to this assignment, Mr. Confeld was a staff engineer in the systems planning group.

A. F. Culbertson (AM '47, M '55) has been appointed director of engineering at Lenkurt Electric Company, Inc., San Carlos, Calif.

Organizational changes in the Tennessee Valley Authority's Office of Power, Chattanooga, Tenn., have been announced. **Merrill DeMerit** (M '40, F '50) is an advisor on engineering and planning activities. **K. E. Hapgood** (AM '25, F '44) is director of the Power Planning and Engineering Division. **J. E. Watson** (AM '47, M '58) heads the Power Marketing Division. The Power System Operations Division is headed by **C. P. Almon, Jr.** (AM '37, F '51). Mr. Hapgood serves on the AIEE Transmission and Distribution Committee (1943-60). Mr. Almon served as AIEE vice-president (1953-55).

K. P. Dowell (AM '43), manager of the service engineering department, Apparatus Division, Texas Instruments Inc., has been assigned to a new department which serves the market for large radar systems in defense and civil air traffic control.

Anaconda Wire & Cable Company has announced the appointment of **A. W. Dunham** (AM '39) as manager of utility sales, with headquarters in New York, N. Y. Mr. Dunham joined Anaconda in 1932

C. P. Durnovo (M '57) has joined the Adler Communication Systems Division as project engineer. Prior to joining Adler, he was project manager at International Standard Electric Corporation.

J. W. Ebbs (AM '51) has been named assistant chief electrical engineer, Rotron Manufacturing Company, Woodstock, N. Y. Before joining Rotron, Mr. Ebbs was a senior project engineer for the Delco Appliance Division of General Motors Corporation at Rochester, N. Y.

A. B. El-Kareh (AM '51) has joined the research staff of the Radio Corporation of America Laboratories at the David Sarnoff Research Center in Princeton, N. J.

A. C. Evans (AM '57) has been appointed chief engineer, research and development, of the Weston Instruments Division, Daystrom, Inc., Newark, N. J. Prior to this appointment, he had been assistant chief engineer.

William Few (AM '39 M '46) has been appointed general manager of manufacturing and **D. F. Willcox** (AM '51) has been named chief engineer of the Furnas Electric Company, Batavia, Ill. Mr. Few has been chief engineer. Mr. Willcox was formerly development engineer.

J. R. Fisher (AM '54) has been appointed product specialist on piezoelectric ceramic materials for the Sprague Electric Company, North Adams, Mass. Mr. Fisher was previously a senior design engineer with the Eastman Kodak Company of Rochester, N. Y.

W. A. Flagg, Jr. (AM '51) has been appointed to the engineering staff of Arthur C. Ruge Associates, Inc., of New England, Hudson, N. H.

E. H. Flath, Jr. (AM '44, M '51) has joined Temco Electronics Division of Temco Aircraft Corporation as a senior scientist to plan developments in the fields of radiation, antennas, and microwave systems.

Harvey Fletcher (M '23, F '30, Member for Life) has been appointed a consultant to Shure Brothers, Inc., Evanston, Ill. Dr. Fletcher is dean emeritus of the College of Physical and Engineering Sciences at Brigham Young University.

H. A. Frey (AM '28, F '51) has been appointed general manager of the insulator department, General Electric Company, Baltimore, Md. He was formerly manager of engineering. Mr. Frey has served on the AIEE Transmission and Distribution Committee (1949-60) and Special Instruments and Auxiliary Apparatus Committee (1956-60).

S. J. Gadler (AM '40, M '52) has been elected a vice-president of Hitchcock & Estabrook, Inc., Minneapolis, Minn. Mr. Gadler is director of the firm's newly established Electronic Division.

J. J. Giba (AM '37) has been appointed acting manager, Tele-Dynamics Division, American Bosch Arma Corporation, Philadelphia, Pa. He had been acting manager of the Chicago Division.

H. W. Giesecke (AM '35, M '42) has been appointed manager of the electronics department, Hydro-Aire Company, Burbank, Calif. Mr. Giesecke was previously general manager of the Capitron Division, Amp, Inc. He has served on the AIEE Electrical Insulation Committee (1958-60).

G. J. Hales (AM '52) has been appointed a member of the board of directors of the Electrical League of Cleveland. Mr. Hales is president of the Adalet Manufacturing Company, Cleveland, Ohio.

W. H. Happe, Jr. (AM '37) has been promoted to the position of general manager, Princeton Division, Curtiss-Wright Corporation, Wood-Ridge, N. J. He had been assistant general manager of the division.

Erich Hausmann (AM '06, F '18, Member for Life), dean emeritus of the Polytechnic Institute of Brooklyn, was presented with the Gano Dunn Medal for Professional Achievement at the Centennial Founder's Day Dinner of the Cooper Union Alumni Association held February 13 in the Hotel Waldorf Astoria. This medal is awarded annually by the association. Dr. Hausmann has served on the following AIEE Committees: Board of Examiners (1920-30, chairman 1925-27), and John Fritz Medal (1957-62).

F. J. Hierholzer, Jr. (AM '51) has been named assistant department head of the microtronics department of Sperry Semiconductor, South Norwalk, Conn.

R. K. Honaman (AM '16, F '36, Member for Life), director of publication at Bell Telephone Laboratories, New York, N. Y., has retired after more than 40 years of Bell System service. Since 1945, Mr. Honaman has directed all public relations activities of Bell Laboratories, including press relations, employee information, advertising, technical and personnel magazines, technical libraries, and community relations. He began his telephone career in 1919 with the development and research department of the American Telephone and Telegraph Company in New York. For the next 20 years, his work dealt principally with the protection of telephone circuits. As assistant protection development engineer, he transferred with his group to Bell Laboratories in 1934.

Mr. Honaman organized the Bell Laboratories' School for War Training at the beginning of World War II to instruct military personnel in radar and related developments. After the war, he was appointed director of publication with responsibility for all publication and public relations programs of Bell Laboratories. During 1954-56, Mr. Honaman was on leave from Bell Laboratories to serve with the Federal Government. He was consultant to the Secretary of Commerce and organized and served as director of the Office of Strategic Information. As Deputy Assistant Secretary of Defense, he had responsibility for the public affairs activities of the Defense Department. He served on the AIEE Publicity Committee (1946-56, chairman 1946-50).

Harry Hyde (M '51) has been appointed general manager and chief engineer of the Toronto Hydro-Electric System, Toronto, Ont., Canada. He was formerly assistant general manager and chief engineer. **Bruce Prentice** (AM '53) has been named assistant to the general manager, engineering, of the Toronto Hydro-Electric System. Mr. Prentice had held the position of executive assistant, engineering.

A. P. Jackel (M '57) had been appointed consulting engineer in the Systems Engineering Section of the general apparatus department of Union Switch & Signal, Division of Westinghouse Air Brake Company, Swissvale, Pa. Prior to this appointment, Mr. Jackel was supervisor of systems design in the general apparatus department.

T. G. LeClair (AM '24, F '40) has become manager of nuclear power applications for General Dynamics Corporation's General Atomic Division in San Diego, Calif. Mr. LeClair had been manager of research and development for Commonwealth Edison Company, Chicago, Ill. His new position is concerned with the expanding development of commercial applications for General Dynamics' advanced power reactor systems. The systems include the high-temperature gas-cooled reactor (HTGR) which is designed to provide a short-cut to the nation's goal of economic nuclear power. A prototype HTGR plant of 40,000 kw is scheduled for completion in 1963. Mr. LeClair has served as AIEE president (1950-51), District 5 vice-president (1946-48), director (1941-45), and as a member of the following AIEE Committees: Protective Devices (1931-45, chairman 1942-43), Edison Medal (1942-44, 1957-62), Registration of Engineers (1942-47, chairman 1946-47), Professional Group Co-ordinating (chairman 1947-50), and Executive (1950-53, chairman 1950-51).

F. C. Lindvall (AM '26, F '43), chairman of the Division of Civil, Electrical, and Mechanical Engineering, and Aeronautics at the California Institute of Technology, has been elected to the board of directors of the Marquardt Corporation. Dr. Lindvall has held his present post since 1945. He has served on the AIEE Education Committee (1951-60).

E. R. Piore (M '55), director of research of International Business Machines Corporation (IBM), New York, N. Y., has been named chairman of the IBM Research and Development Board. **W. W. McDowell** (AM '52), formerly vice-president for research and engineering, has been appointed resident vice-president for IBM's extensive operations in Endicott, N. Y. Mr. Piore has served on the AIEE Edison Medal Committee (1958-63).

Z. W. Pique (M '49), recently a marketing executive with Hughes Aircraft Company and Texas Instruments, has been appointed vice-president—marketing of Hoffman Electronics Corporation, Los Angeles, Calif.

R. W. Scott (AM '54) has been named administrative engineer in the Engineering Division of Crouse-Hinds Company, Syracuse, N. Y. He returned to Syracuse recently from Detroit, Mich., where he had been Crouse-Hinds' Great Lakes Division manager. Mr. Scott has served on the AIEE Chemical Industry Committee (1955-60).

H. P. Sedwick (M '32) received the 1960 Washington Award of the Western Society of Engineers. He was honored ". . . for leadership and achievement in electric and gas utilities, for true service in educational and humanitarian fields, and for developing young engineers." Mr. Sedwick retired in 1958 as president of the Public Service Company Division of Commonwealth Edison Company after almost 45 years in the Chicago, Ill., area utility industry. During that time, he was responsible for engineering and directing the development of many innovations and improvements in the operations of electric and gas systems.

T. G. LeClair

Town & Country

H. P. Sedwick

OBITUARIES*

Robert Hamilton Barclay (AM '14, M '18, F '28 Member for Life), consulting engineer, J. G. White Engineering Corporation, New York, N. Y., died recently. Mr. Barclay was born August 10, 1887, in St. Louis, Mo. He took his technical training at Washington University, St. Louis. During 1908-11, he was employed by the Bell Telephone Company of Missouri, St. Louis, and the Missouri and Kansas Telephone Company, Kansas City, Mo., as chief draftsman, telephone engineer, and superintendent of buildings and power plants. For the next 3 years, he was an assistant electrical engineer of the Kansas City Terminal Railway Company, Kansas City, Mo. Mr. Barclay was assistant engineer of the Brooklyn-Manhattan Transit Corporation, Brooklyn, N. Y., during 1915-17. During 1917-34, he was associated with the Foundation Company, New York, as chief electrical engineer; Starrett and Van Vleck, architects, New York, as chief electrical engineer; Stone and Webster Engineering Corporation, Boston, Mass., as electrical engineer; and McClelland Barclay Art Products, Inc., New York, as president. In 1934, he joined the Federal Power Commission in Washington, D. C., as chief of the analysis and reports division. He was regional director of the commission in New York during 1936-41. Mr. Barclay resigned from this position in 1941 to join the White Engineering Corporation, taking charge of all its electrical engineering and construction. He remained active as a consulting electrical engineer after his retirement from J. G. White in 1957. He was a registered professional engineer in the State of New York. Mr. Barclay served on the following AIEE Committees: Marine (1918-19), Board of Examiners (1943-59, chairman 1946-48), and Engineers' Council for Professional Development (1950-56).

Thurman Judson Bell (AM '44, M '55), Northern Division meter supervisor for the Carolina Power & Light Company, Raleigh, N. C., died recently. He was born January 19, 1907, in Spencer, N. C., and received the B.S. degree in electrical engineering from North Carolina State College in 1928. Following graduation he was associated with the Duke Power Company in Charlotte, N. C., until 1935 when he joined the Carolina Power & Light Company in Raleigh as a meter engineer.

Alfred Peter Skillman Bellis (AM '26, Member for Life), retired chief electrical engineer for the John A. Roebling's Sons Division of the Colorado Fuel & Iron Corporation, died recently at the age of 78. He received the mechanical engineering degree from Lehigh University in 1909. Mr. Bellis had been associated with the company since 1900. He retired in 1948 and served as an adviser on engineering matters since then. In 1901, he was electrical engineering supervisor for

* Due to a misunderstanding, an obituary on George J. Christ appeared in the April issue. Mr. Christ is not deceased. His name was used mistakenly instead of James A. Crist, another New York Telephone Company engineer, who died in February.

the 5-mile Roebling-built submarine cable providing telephone service from Baltimore across Chesapeake Bay. During World War I, he was superintendent in the Electric Wire and Cable Division of the company. He was appointed assistant general manager in the company's Insulated Wire Division in 1924 and remained in this division until his retirement as chief electrical engineer. Mr. Bellis served on the AIEE Insulated Conductors Committee (1947-48).

Jesse Hood Davis (AM '03, Member for Life), chief engineer of electric traction for the Baltimore & Ohio Railroad Company until his retirement in 1938, died recently. Mr. Davis was born October 7, 1876, at Forrest City, Ark., and received the electrical engineering degree from the University of Arkansas in 1897. He was employed in the electrical department of the Pennsylvania Railroad, Altoona, Pa., during 1901-05, and then joined the Baltimore & Ohio as an assistant electrical engineer. For 4 years, he was actively engaged in the application of axle generators for lighting of passenger cars to supersede oil and gas lighting. He designed and prepared specifications for power plant improvements throughout the system and supervised the installation of modern stationary type of boilers and electric generating equipment. In 1909 he was promoted to electrical engineer, and in 1924, chief engineer—electric traction. He continued with his previous duties, and in addition was made responsible for the design, construction, installation, and placing in operation of the electrified facilities for modern multiple unit car operation on the Staten Island Lines, an assignment which was completed in 1926. In recognition of the Staten Island electrification, the degree of electrical engineer was conferred upon him by the University of Arkansas. Mr. Davis designed and tested the first completely equipped air conditioning railway passenger car for the Baltimore & Ohio in 1929. In 1930, a colonial dining car was completely air conditioned and placed in commercial service. In 1932, a research plant was installed in Baileys, Baltimore, Md., by the Baltimore & Ohio at his request for the purpose of developing the possibilities of the use of radio waves for insect extermination. In 1940, he developed a plan used later by the British Navy to clear the mine-clogged Suez Canal. Mr. Davis's technique involved a highly sensitive synthetic material of aluminum, nickel, and cobalt that a barge or low-flying plane would carry across the canal to detonate German mines. He served on the AIEE Industrial and Domestic Power Committee (1916-17) and Standards Committee (1933-34).

J. H. Davis

John William Gore (AM '41, M '44), electrical and welding engineer, Bethlehem Steel Company, Shipbuilding Division, Baltimore Yard, Baltimore, Md., died recently. Mr. Gore was born October 4, 1895, in Belfield, Va., and studied at Johns Hopkins University in Baltimore. Since 1917, he had been with the Shipbuilding Division of Bethlehem Steel where he was responsible for all electrical engineering, welding sequences, techniques, and procedures at the Baltimore Yard. Since 1948, he had been a member and secretary of the Maryland State Board of Registration for Professional Engineers and Land Surveyors. Mr. Gore had served as president of the National Council of State Board of Engineering Examiners, as the council's representative to the Dominion Council of Professional Engineers in Canada, and as a member of the National Bureau of Engineering Committee and the Committee on Future Operation of Council. He was a member of the American Welding Society and its chairman for the Maryland Section. Mr. Gore was a past chairman of the Maryland Section, AIEE (1950-51), and served on the AIEE Electric Welding Committee (1949-51).

Marmion S. Oldacre (AM '13, M '42, F '47), Member for Life), formerly director of research, Utilities Research Commission of Commonwealth Edison Company, Chicago, Ill., died recently. Mr. Oldacre was born January 8, 1889, in Chicago, Ill., and received the B.S. degree in electrical engineering from Purdue University in 1910. He began work for Commonwealth Edison in 1910 in the station construction department. In 1912, he was transferred to the testing department. In 1919, he was employed by the Westinghouse Electric and Manufacturing Company, Chicago, as an engineer in the stoker engineering department. He became a sales engineer for Westinghouse in 1923. In 1926, he returned to Commonwealth Edison as an engineer. He was promoted to research engineer of Commonwealth Edison in 1935, equipment and research engineer in 1937, and staff engineer in 1945. He became director of research, Utilities Research Commission of Commonwealth Edison Company in 1946. He retired from the company before his death. Mr. Oldacre served on the following AIEE Committees: Electrical Machinery (1939-47, chairman 1946-47); Standards (1943-48); Transfers (1943-45); Award of Institute Prizes (1946-47); Technical Program (1946-47); Nucleonics (1950-58), Research (1955-58, chairman 1957-58); Technical Operations (1957-58); and District 8 representative on the Technical Operations Department (1957-58).

Arthur Fisher Rose (AM '19, M '22, F '51, Member for Life), engineer with the American Telephone & Telegraph Company, New York, N. Y., until his retirement, died recently. He was born June 9, 1893, in New York, N. Y., and received the B.S. degree in electrical engineering from Colorado College in 1914. After graduation, he joined American Telephone & Telegraph as an engineer in New York. Miscellaneous engineering assignments included field work on the first transcontinental telephone line. During 1919-21, he worked on a survey of telephone conditions in Cuba in relation to installation of Cuban-American Telephone Company cables. In 1921-32, he was assigned to engineering and supervisory work on general transmission problems and multiplex systems. He worked on the preparation of engineering practices for guidance of field forces. Mr. Rose had supervisory charge of exchange area transmission studies, radio, telephotograph, and other special services in 1932-39. In 1939, he was given supervisory charge of the general planning of toll plant extensions for the Bell System. After retiring 2 years ago, Mr. Rose was a consultant for the company. He was a senior member of the Institute of Radio Engineers and a member of the Acoustical Society of America.

Uriah Sidney Shuman (AM '37), electrical project engineer, Philadelphia Electric Company, Philadelphia, Pa., died March 3, 1960. He was born December 3, 1897 in Thompsontown, Pa., and received the B.S. degree in electrical engineering in 1923 from Drexel Institute of Technology. Following graduation, he was employed for a short time by the Bell Telephone Company. His service with Philadelphia Electric began in 1923. In 1929, he was transferred to the Electrical Engineering Division, where after 4 years as a relay engineer he specialized in electrical design for generating stations. He was a registered professional engineer in the State of Pennsylvania.

Howard Saunders Warren (AM '03, M '08, F '13, Member for Life), director of protection development at the Bell Telephone Laboratories before his retirement in 1938, died recently at the age of 86. Mr. Warren was born in Old Town, Me., and graduated from Stanford University. In 1898, he went to work for the American Bell Telephone Company in Boston, Mass. When its laboratories were transferred to New York in 1907, he went along as the firm's specialist in inductive co-ordination. He contributed to the Bell System's work on electrification programs of the country's major railroads. He also participated in the work of the joint subcommittee on the development and research of the Edison Electric Institute and the Bell System. He was a fellow of the American Association for the Advancement of Science. Mr. Warren was a member of the following AIEE Committees: Safety (1915-40, chairman 1935-37); Traction and Transportation (1916-17); Power Transmission and Distribution (1925-41); National Fire Protection Association, Electrical (1932-34 alternate, 1935-37 representative, 1938-43 alternate); National Safety Council, Low Voltage Hazards (1935-40); and Board of Examiners (1930-45, chairman 1943-45).

OF CURRENT INTEREST

WORKMAN and bulldozer are dwarfed by the "bigger than a football field" antenna reflector for the U. S. Air Force's BMEWS surveillance radar subsystem which towers 165 feet into the Arctic sky. The reflector's surface is made up of 2,240 5- by 7-foot steel screen panels, each of which is bolted to the truss structure. More than 4½ miles of nickel steel pipe varying in size from 6 to 12 inches in diameter, and ⅜ to 1⅜ inches in wall thickness were used in constructing the huge reflectors, which were manufactured by the D. S. Kennedy Company of Cohasset, Mass., in accordance with General Electric Company design specifications.

Surveillance Radar Subsystem For Air Force's BMEWS, Site 1

THE LARGEST long-range surveillance radar subsystem in the Free World is being installed in the Arctic at the U. S. Air Force's Ballistic Missile Early Warning System (BMEWS) Site 1, according to T. I. Paganelli, manager of the General Electric Company (GE) missile detection systems section, heavy military electronics department, Syracuse, N. Y.

Developed in co-operation with the Air Force's Air Research and Development Command, this long-range surveillance radar system will generate a gigantic curtain of r-f energy over the northern polar regions, insuring the detection of intercontinental ballistic missiles at distances of several thousands of miles.

BMEWS, for which the Radio Corporation of America (RCA) is the prime contractor, is designed to provide about a 15-minute warning for the North American Air Defense Command, the Strategic Air Command, and Civil Defense agencies in case of a missile attack on the North American Continent. Wherever possible, it will use existing communications, including those already installed for the DEW (Distant Early Warning) line in Canada and Alaska.

PIERCING the Arctic sky are the 60-foot-long backstays for the BMEWS surveillance radar subsystem antenna reflectors. A total of 20 backstays and 20 trusses support each of the 1,500-ton reflectors. Each backstay is 42 inches in diameter and weighs 7½ tons. Some 10,000 cubic yards of concrete were poured in the 160 foundation footings needed for the antenna reflector supports.

The heart of the long-range detection radar subsystem developed and produced by GE's heavy military electronics department is a combination transmitter-receiver unit which transmits many times each second an extremely brief burst of energy, at a power level which is greater than that transmitted by a total of 100 large radio stations.

After each of these radar pulses, the transmitter automatically shuts down and an extremely sensitive receiver listens for the tiny echo being reflected from the target, which may be thousands of miles away. The echo reflected from long-range targets will not contain enough energy to light the smallest lamp bulb.

The receiver side of the unit is automatically blocked off for a few microseconds while the high-energy radar pulse is being transmitted. Then the transmitter side of the unit must be blocked off so as not to interfere with the radar's receiving capabilities. This complete cycle is programmed many times per second.

A component known as a modulator acts as an electronic switch, or valve, to furnish the high voltage to the transmitter in short pulses, and to control the transmitter's off-time, permitting the receiver to pick up any signal reflected from a target.

When a target reflects a radar echo, this extremely weak r-f pulse is converted into video pulses and fed into a video-amplifier. Here the pulse is increased and

fed into an indicator, or scope, where it can be spotted visually as a potential target. Since radar pulses travel at the rate of 186,000 miles per second, very accurate measurements of time in microseconds must be made to control accurately the radar's transmission and receiving cycle, and to measure the distance to the target.

More than 21 miles of waveguide are needed to direct the r-f energy generated by the transmitters through miles of passageways to the high-speed scanning switch and the antenna feedhorns which bounce the energy off huge antenna reflectors, each larger than a football field.

Because of the extreme arctic conditions which are unusual to radar installations, it was necessary to design the 165-foot-high 400-foot-wide torus-shaped reflectors to withstand severe cold and hurricane-like winds. In addition, the special chrome-nickel steel structures are built to withstand a 6-inch coating of ice, which might double the weight of the reflector.

In the usual radar antenna design, the feedhorn reflectors and other equipments are combined as one unit. However, the gigantic size of the BMEWS surveillance radar subsystem requires a separate building to house the scanning switches, waveguides, and feedhorns. Extremely close tolerances were required throughout all phases of construction.

One of the problems solved in the unique design of the scanner building was to make proper provisions for the different rates of expansion between the steel beams, which must be exposed to the arctic temperatures, and those which are enclosed in heated areas.

The reason for this concern, and resulting requirement for extreme accuracy in construction is that the 704 feedhorns necessary for this system must be set to within 1/16-inch tolerance, in order to bounce the r-f energy off the huge reflectors at the precise angle for the required coverage.

The waveguide, which transmits the r-f energy from the transmitter to the feedhorns, has the external appearance of oversized heating and ventilating ducting used in home hot-air systems. However, the aluminum waveguide must be accurately constructed, polished internally, and cleaned thoroughly to prevent arc-over of the very high level r-f energy. Any scratches or small dents make the waveguide unserviceable. Careful handling was one of the major transportation problems in shipping the required 21 miles of aluminum waveguide, which weigh a total of 1,500 tons, into the arctic area.

The connecting flanges between the lengths of waveguide are machined to a 63-microinch finish and each of the 24 connection bolts must be tightened with a torque wrench to assure uniform tightness. All welding is external, leaving the inside of the waveguide with a smooth finish.

More than 200 hp is required to run the compressors which dehydrate the air before it is pumped into the massive pressurized waveguide system. Hot air is blown over the plastic windows of the exposed feedhorns to prevent ice formation during the subzero arctic weather. A special sensing device automatically regulates the flow of hot air to the deicer units.

An estimated 27 million pounds of equipment are necessary for this super surveillance radar system. The complexity of the logistics problem can be visualized by the approximately 17,000 packaging units needed to ship the material to the Arctic where the sea lanes are open just 3 months of the year.

A total of 450 businesses, both large and small, have supplied equipment for the radar subsystem in accordance with GE design specifications. An estimated 42% of these suppliers are small business firms each with less than 500 employees. Likewise, 44% of the dollars subcontracted have gone to small business.

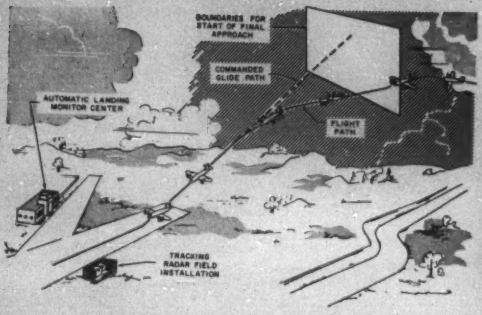
GE's heavy military electronics department is responsible for designing, developing, producing, testing, and placing in operation the surveillance radar subsystem for BMEWS under a subcontract with RCA.

Testing of Elements

Transmitting, receiving, and signal processing elements of the BMEWS surveillance radar subsystem are being tested in GE's High-Power Radar Laboratory, Syracuse, N. Y., thousands of miles from Site 1 in the Arctic.

To facilitate tests required on the complex electronic equipment, the 28,000-square-foot laboratory is equipped with a transmitter capable of generating r-f power at multimillion-watt levels. The power from 34,000-volt incoming transmission lines is converted by banks of high-voltage regulators, transformers, rectifiers, and capacitors to the 120,000-volt d-c supplies required by the transmitter. Groups of 9-foot-high klystron tubes are used to generate the powerful pulses required for testing. EE

ONE of the high-power klystron tubes in the BMEWS surveillance radar subsystem is shown being installed for test (*right*) at the GE High-Power Radar Laboratory. Large focusing coils encircle the 9-foot tube. Tube shown is manufactured by Eitel-McCullough Company of San Bruno, Calif. Below: Electron probe duplexers, newly designed for use with BMEWS, are shown being tested in a resonant ring at the GE laboratory. These duplexers protect the supersensitive receiver circuits by blanking off the receiver inputs while the transmitter is radiating. When the radar system is "listening" for target returns, or echoes, the duplexers permit extremely weak r-f signals to flow into the receiver. This transmit-receive cycle takes place many times a second. Being tested in the background is the high-speed scanning switch, which is housed in a large tank. This scanning switch is designed to transmit multimillion-watt pulses of r-f energy and to receive millimicromicrowatt return signals. This difference in power levels is approximately the same as the difference between the size of the earth and a basketball.



ARTIST'S SKETCH *(above, left)* **shows how all-weather automatic landing system picks up incoming airplane as it passes through electronic "window" from 2 to 4 miles from end of runway and guides it to proper glide path and touchdown. The system, developed by Bell Aircraft Corporation, now is being evaluated by the Federal Aviation Agency for possible military and commercial application.** *Above, right:*

FAA laboratory C-54 flies low past aircraft landing equipment at National Aviation Facilities Experimental Center during preliminary evaluation of the system. Radar antennas which track two incoming airplanes simultaneously are in center of photo. The automatic landing system has landed the C-54 as well as an Air Force F-86 jet within seconds of each other.

Automatic Landing System Lands Two Planes a Minute

AN automatic aircraft landing system capable of landing two airplanes a minute during adverse weather is being evaluated by engineers of the Federal Aviation Agency (FAA) at the National Aviation Facilities Experimental Center, Atlantic City, N.J.

The system, developed for the U. S. Air Force by the Avionics Division of Bell Aircraft Corporation, Buffalo, N.Y., uses radar to track the airplane and radio to transmit control instructions to the plane's automatic pilot.

An FAA 4-engine C-54 laboratory airplane and an F-86 Air Force jet fighter have been landed automatically during the initial phase of the tests, which are expected to take 6 months.

Described as the most modern, all-weather, automatic landing system in existence today, it may be integrated into traffic control systems at high-density airports or operated as a landing aid at underdeveloped airfields.

Advantages Offered

The obvious advantage of the system is that it may eliminate stacking of airplanes over busy airports in bad weather, thus providing an essential time-saving factor in commercial multijet operations.

The equipment also could be used to land some guided missiles and space vehicles. It has landed Regulus II, a surface-to-surface guided missile.

The Bell Aircraft system provides fully automatic "hands off" control of the airplane throughout final approach and touchdown on the runway, but the pilot may take over control at any time.

In its present military configuration, the system, designated AN/GSN-5, consists of an operations trailer, housing the electronic control equipment and two radar screens, two radar antennas, and a power trailer.

These units are positioned near the runway for the tests which are underway, but in the final configuration the system itself will be installed in the airport control tower or administration building with only the radar antenna actually on the field.

To land an inbound airplane, the precise tracking radar "locks on" the plane when it flies through an electronic window or gate from 2 to 4 miles from the end of the runway. It is at this point that the pilot relinquishes control of the airplane to the system.

Should the airplane be too high or too low, too far to the right or too far to the left, corrections are transmitted to the plane's automatic pilot.

The airplane appears as a small dot on the radar screens in the operations trailer, permitting the monitors to check its position in relation to the desired altitude and the center of the runway.

The two separate radar systems permit handling two inbound airplanes simultaneously.

Function of the monitors is to determine only whether the equipment is operating properly. All control is provided entirely and automatically by the electronic system.

Safety Features

If the airplane is not maintaining the proper rate of descent or glide path or if it is not aligned with the runway, the system gives it an automatic "wave off."

An additional safety feature provides for a "wave off" when a second airplane is in danger of overtaking the first in the landing sequence.

Another advantage of the system, according to Bell Aircraft engineers, is that it provides for precise and reliable landings regardless of weather conditions.

Unlike other existing automatic landing systems, the engineers point out, no complex electronic equipment is needed in the airplane other than the standard autopilot and instrument landing system.

A small aluminum corner reflector, designed to strengthen the reflected radar signal, is the only item which has to be installed on the airplane.

Originally designed for the U. S. Navy for installation aboard aircraft carriers, the system has landed various airplanes, including the Boeing 707 and the Air Force B-47, more than 4,000 times on land and on a carrier deck during its development. **EE**

First Missile-Borne TV Successfully Demonstrated

A missile-borne television camera, designed to report instantly the results of a missile firing, was successfully launched for the first time at the U.S. Army's White Sands Missile Range recently, it was announced by A. L. Malcarney, executive vice-president, RCA Defense Electronic Products.

Radio Corporation of America (RCA) provided both the air-borne television equipment and the ground receiving equipment.

Mr. Malcarney said that the feasibility test holds great importance for the national defense in that an Army field commander using a television reconnaissance device would know immediately whether the missile had destroyed the target and the amount of damage created. He would also have vital information on which to base further action.

In the recent test, the miniature television camera and transmitter were housed in a small capsule contained in the missile and ejected during flight. As the capsule, slowed down by its aerodynamic design, fell gradually to earth, it transmitted

high-resolution television pictures of the target area in which the missile was about to land. Still aloft after the missile warhead's impact, the television capsule continued to transmit pictures.

The television capsule was developed for Army Ordnance over a 15-month period by RCA in co-operation with the Chrysler Corporation Missile Division, both working with the Army Ballistic Missile Agency and the Research and Development Laboratories of the U. S. Army Signal Corps.

The television capsule at White Sands Missile Range was ejected from the Redstone ballistic missile at 40 miles altitude. The receiver for the pictures transmitted during the firing was located 75 miles from the impact point. The pictures also were recorded on video tape to permit Army engineers to study the results.

"The television system incorporates a new video technique called 'slow scan,' which results in a series of high resolution still pictures," Mr. Malcarney said. "The slow scan technique makes possible transmission of high-quality pictures to the ground receiver, using a very narrow bandwidth."

The quality of the television picture, he said, is better than that of commercial television and requires only 1/100 of the bandwidth normally required to transmit such a picture.

Both the television circuitry and the transmitter contained in the capsule are fully transistorized. **EE**

Device Lets Astronaut "See" His Position Over Earth

A device that will enable the nation's first orbiting astronaut to "see" where he is over the earth at all times has been developed by Minneapolis-Honeywell Regulator Co. for Project Mercury.

The device, called an Earth Path Indicator, will be the prime source of position information if the astronaut loses contact with ground tracking stations, it was stated.

The Indicator contains a globe-like replica of the earth which revolves slowly to duplicate the position of the earth under the orbiting capsule.

The astronaut views the globe through a window on his instrument panel in the same manner as if he were actually seeing the earth below him through a window in his capsule.

The Earth Path Indicator grew out of human factors studies conducted by the firm's Aeronautical Division for McDonnell Aircraft Corporation, prime contractor on the Mercury capsule.

The Indicator was developed to supplement electronic navigation equipment on the ground and in the orbiting capsule. It is mechanically powered for independent functioning.

Information provided by the Indicator will become critical at the time the astronaut fires the rockets that will return him to earth. The capsule is designed to land safely in water, and a miscalculation of position could cause the astronaut to hit land instead.

The earth replica inside the indicator has markings which include longitude, latitude, continents, topography, and major cities. Calibrated lines on the window of the instrument give the astronaut his position over the earth and his landing area 3,000 to 4,000 miles from that position.

The Earth Path Indicator will be set by the astronaut after he reaches orbit, based on information relayed to him from ground tracking stations.

The device has four adjustments to correspond to the capsule's orbit path and speed. These adjustments are for the earth's polar east–west rotation, the capsule's position in orbit path, inclination to the equator, and orbit period or time. The inclination adjustment is from 28 to 40 degrees and the orbit period from 5,200 to 5,400 seconds, approximately 1½ hours.

The globe revolves, just as the earth, around a north-south axis, while at the same time revolving around an axis perpendicular to the orbit plane to duplicate

SPACE CAPSULE instrument which may be vital to the first United States astronaut in orbit undergoes final adjustment at Minneapolis-Honeywell's Aeronautical Division. The grapefruit-size globe in the instrument will revolve to correspond to the movement of the earth under Project Mercury's orbiting space capsule. The astronaut will view the slowly revolving globe through the instrument's window (lower left) in the same manner as if he were actually seeing the earth below him through a window in his capsule. The instrument will tell him where he is in relation to countries, oceans, and cities, information of critical importance when he fires the rocket to return to earth.

the capsule's travel. The complexity of the Earth Path Indicator results from the fact that the globe revolves in two directions simultaneously and at the same time has the capability of adjustment to any orbit path.

The globe, which has a diameter of approximately 4 inches, is made of hollow aluminum coated with acrylic plastic. The map was silk screened onto the inside of the plastic to prevent marring. **EE**

Future Meetings of Other Societies

Instrument Society of America
3rd National Power Instrumentation Symposium, May 9-11, San Francisco State College, San Francisco, Calif. ISA, 313 Sixth Ave., Pittsburgh 22, Pa. *Summer Instrument-Automation Conference and Exhibit*, May 9-12, Civil Auditorium & Brooks Hall, San Francisco, Calif., same.

ASM, 2nd Southwestern Metal Congress and Exposition, May 9-13, Sheraton-Dallas Hotel & Texas State Fair Park, Dallas, Texas. J. Stratton, American Society for Metals, Metals Park, Novelty, Ohio.

SPSE, National Conference, May 9-13, Miramar Hotel, Santa Monica, Calif. Society of Photographic Scientists & Engineers, Box 1609, Main Post Office, Washington, D.C.

Symposium on Superconductive Techniques for Computing Systems, May 17-18, Department of Interior Auditorium, C St., N. W., Washington, D.C. J. Leno, Code 430A, Office of Naval Research, Washington 25, D.C.

Society for Experimental Stress Analysis, Spring Meeting, May 18-20, Hotel Severin, Indianapolis, Ind. Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Mass.

Design Engineering Show & Conference, May 23-26, New York Coliseum, New York, N.Y. Banner & Grief, 369 Lexington Ave., New York 17, N.Y.

Institute on Recent Advances in Solid-State Devices, June 1-2, Department of Electrical Engineering, Marquette University, Milwaukee, Wis. Stanley Krupnik, Jr., Assistant Chairman of Electrical Engineering, same.

6th Annual Radar Symposium, June 1-3, Ann Arbor, Mich. The University of Michigan, Willow Run Laboratories, Ann Arbor, Mich.

ASME, Summer Annual Meeting & Aviation Conference, June 5-9, Statler Hilton Hotel, Dallas, Texas. L. S. Dennegar, The American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N.Y.

British Exhibition (including electrical and electronics industries), June 10-26, New York Coliseum, New York, N.Y. A. A. Schechter Associates, 551 Fifth Ave., New York 17, N.Y.

ANS, 6th Annual Meeting, June 12-15, Palmer House, Chicago, Ill. American Nuclear Society, John Crerar Library, 86 E. Randolph St., Chicago, Ill.

8th Annual Technical Writers' Institute, June 13-17, Rensselaer Polytechnic Institute, Troy, N.Y. Prof. J. R. Gould, same.

Overseas

8th International Automobile Technical Congress, May 9-13, The Hague, Netherlands. General Secretariat, 14, Burgemeester de Monchyplein, The Hague, Netherlands.

Conference on Automatic Computing and Data Processing in Australia, May 24-27, Univ of Sydney and Univ. of New South Wales, Australia. C.H.D. Harper, Australian Natl. Committee on Computation and Automatic Control, The Institution of Engineers, Science House, 157 Gloucester St., Sydney, Australia.

International Congress on Microwave Tubes, June 7-11, Munich, Germany. R. D. Paine, Jr., National Science Foundation, Washington 25, D.C.

International Conference on Large Electric Systems (CIGRE), 18th Convention June 15-25, 112 Boulevard Haussmann, Paris 8, France.

IFAC, 1st International Congress, June 27–July 27, Moscow. The Organizing Committee of the USSR National Committee for Automatic Control, Kalanchevskaja ul. 15-a, Moscow 1-53, USSR; American Express Co., 65 Broadway, New York 6, N.Y.

THESE microwave relay antennas, strung across Nevada's snow-swept mountains, feature "automatic defrosters"—special gas unit heaters designed by Reznor Manufacturing Company. The heaters, mounted atop antennas, prevent ice formations which could reduce the transmission range of the antennas. The 10-foot diameter antennas are a vital part of Bell Telephone Company of Nevada's cross-country communications links.

"Automatic Defrosting" for Microwave Relay Antennas

Microwave relay antennas strung across Nevada's snow-swept mountains now feature a new "automatic defrosting" system designed to help keep them at peak transmission efficiency.

The "defrosters"—special snorkel-type gas unit heaters built by Reznor Manufacturing Company, Mercer, Pa.—are designed to prevent transmission problems which occur when ice forms on the 10-foot-diameter parabolic antennas, and reduces their range.

The heaters were built for the Gabriel Electronics Division of The Gabriel Company, Millis, Mass., which produces microwave antennas for Western Electric Company, supplier for Bell Telephone Company of Nevada's cross-country communications links.

"The Nevada link crosses mountain areas which have extreme snow conditions during the winter months," Stanton Yarbrough, president and general manager of the Gabriel Electronics Division, said. The antennas are spaced about 50 miles apart. Since the nearest manned control stations are 30 miles from any of the antennas, an automatic and economical method is necessary to melt the snow off the antennas and to keep ice from forming on them.

The special, enclosed heaters are fueled from liquified propane gas reservoirs at each antenna site. A heater is mounted atop each antenna, and air, heated to 130 F, is blown through ducts across the antenna, melting any snow or ice formations.

The heaters are fitted with snorkels which provide combustion air to the burners, as well as a vent to expel products of combustion to the atmosphere. The snorkels permit the gas heaters to function at top efficiency in winds up to 70 mph.

The special heaters are thermostat-controlled to operate when temperatures range between 20 and 38 F—the temperature range which is conducive to ice formation. An automatic electric igniter lights the gas flame.

The heaters each have a thermal output of 60,000 Btu and operate on 115-volt 60-cycle line current. Their operation is designed to be as completely automatic as possible, making maintenance practically nil. A built-in alarm system alerts personnel at control stations should the heaters malfunction. **EE**

Microsecond Memory Drives Metallic Contacts

A very fast electromechanical switch called the "ferreed" has been invented by a team of engineers at Bell Telephone Laboratories. It utilizes a new technique for actuation which is compatible in speed with electronic circuits.

The ferreed may find use as an interconnecting element in telephone switching networks, where it could be controlled a thousand times more rapidly than switches presently employed.

Inventors of the new switch, A. Feiner, C. A. Lovell, T. N. Lowry, and P. G. Ridinger, are members of the technical staff of the Bell Telephone Laboratories. They anticipate applications for the ferreed in various types of systems where advantage may be taken of metallic contacts controllable by current pulses of a few microseconds duration.

Magnetic materials that can be switched quickly between two alternate states have been widely used as "memories" for storing information in digital computers. Generally, the useful output from these elements has been limited to electrical signals of a transistory character.

In conventional electromagnetic relays, however, continuous electric currents can be used to open and close metallic contacts for extended periods of time, but at speeds limited by the mechanical motion of the moving parts.

The ferreed combines the rapid switching of bistable magnetic material with metallic contacts for output indications that persist as long as desired without further application of power. In several models of the device, a cobalt ferrite has been used as the magnetic material and a glass-sealed magnetic reed switch for the output contacts—hence the name, "ferreed."

In operation, the magnetic material is switched by a magnetomotive force applied, typically, as a 5-ampere current pulse in a 30-turn winding. Control pulses as short as 5 microseconds will switch the magnetic material, resulting in the passage of magnetic flux through the movable members of the reed switch. Actual closure of the contacts is delayed by inertia of the reeds for several hundred microseconds.

Release of the contacts is brought about by cancellation of the magnetic flux through the reeds, as the result of another 5-microsecond switching operation. Opening of the contacts requires less time than the closing operation.

Several new magnetic materials have been synthesized for use in developmental models of the ferreed. Among these are ferrites exhibiting characteristics midway between permanent magnets and computer memory materials, and ferrite suspensions in plastic "tailor-made" for specific magnetic, electrical, and mechanical properties. The reed switch is similar to a type used in standard electromagnetic relays for the past decade.

In a telephone switching network, subscribers are interconnected by the closure, in specified patterns, of switches called "crosspoints." A typical central telephone office contains many thousands of these switches; of these, a few dozen

THE FERREED, developed at Bell Telephone Laboratories, is a very fast electromechanical switch with metallic contacts, requiring no holding power. In the 2-branch ferreed shown, two ferrite bars, two glass-sealed magnetic reed switches, and two plastic end-pieces comprise the magnetic circuit. Nonconducting electrically, the plastic end-pieces magnetically couple the ferrite bars to the magnetic reed switches, at the same time providing a good structural support for the assembly. The passage of magnetic flux through the movable metallic members of the reed switch closes a circuit. Control pulses of 5 microseconds through the windings on the ferrite will switch the magnetic material.

are operated for each call. Those crosspoints required for a particular connection must be selected by the coincidence of pairs of control pulses. The ferreed's magnetic structure responds to a pair of pulses by closing the output contacts. They are opened by a subsequent single pulse.

Besides coincident pulse operation and rapid actuation, the magnetic structure permits the desired switching by current pulses of widely variable character.

The result, when ferreeds are used in switching networks, is reliable operation from simple control circuits. **EE**

Color "Pleasantness" Depends on Background Hues

No color is intrinsically good or bad, pleasant or unpleasant. Its appeal depends upon the hue of background and the nature of the illuminant under which it is seen.

These were among the interim conclusions presented by Dr. Harry Helson, professor of psychology at the University of Texas (Austin) and a leading authority on color, midway in a study of 156,200 reactions by 10 subjects to 125 different Munsell colors viewed against 25 different backgrounds under 5 different kinds of illuminants. Dr. Helson delivered his interim report at the third research symposium of the Illuminating Engineering Research Institute, sponsor of his study.

Dr. Helson said that even though a person might be certain that his "favorite color" is blue, the appearance of blue in various degrees of lightness (the amount of light reflected from the specimen) and saturation (the strength or density of the pigmentation) against certain backgrounds with various sources of light could be unattractive or even repulsive to him.

Thus, one of the objects of Dr. Helson's studies is to develop a series of charts to indicate "families of color pleasantness" for the use of architects, interior decorators, and housewives which would indicate the range of attractiveness of hues in the spectrum in relationship to specific background and lighting. This would constitute a long step toward achieving enjoyable and comfortable environments for living and working areas, he pointed out.

Dr. Helson anticipates that, after further analyzing the 156,200 judgments of his subjects—six men and four women—now being done with the use of electronic computers, he will also be able to plot for the first time with scientific validity, such information as: the most agreeable backgrounds indicated for a particular existing hue; the most agreeable hues for combination with an existing background; and the light sources that will produce the pleasantest effects from a given combination of Munsell colors and their related backgrounds.

Dr. Helson's tests were conducted with a color booth in which standard Munsell color swatches were mounted against a fixed solid-color background and viewed successively under five illuminants, each with a different "color temperature" or with light resulting from a different source. Munsell colors are a series arranged in steps of difference which it is possible for the eye to perceive. The five illuminants used were: 6500 K (Kelvin measurement), a tungsten incandescent filament with a blue filter which developed a "color temperature" of 6500 K known as "daylight"; 6500 K fluorescent; 4500 K fluorescent, known as cool white; 3000 K fluorescent, known as warm white; and 2854 K incandescent, a tungsten filament in a clear white bulb.

His subjects classified the appearances of the colors according to their personal reactions in relation to a 9-stage scale ranging from very, very pleasant through neutral to very, very unpleasant.

The 4500 K cool white fluorescent, in evaluations thus far established, proved to be the illuminant that produced the most pleasant reactions for the subjects in viewing the 125 Munsell colors against 20 different backgrounds ranging from white to purple-blue.

The most pleasant background proved to be white. The next seven most favorable reactions, in numerical order were: dark green pastel (pastels have low saturation); light yellow pastel; light yellow, high saturation; light green pastel; light red pastel; purple-blue pastel; and gray.

The least pleasant background was medium-dark purple-blue in medium saturation. Others at the bottom of the judgment list, each a little more pleasant than the preceding background, were: medium-dark green, medium saturation; medium-dark yellow-red, heavy saturation; medium dark red, medium saturation; and medium dark red, heavy saturation. **EE**

Radar Antenna Test Pattern Fixture

How much is a radar receiver "fooled" by the radome in which it is mounted? This question is being answered with the aid of a new radar test tower now in use by the General Electric Company (GE) heavy military electronics department at its antenna development facility near Cazenovia, N.Y.

Designed and built to GE specifications by the E. W. Bliss Company at its Canton, Ohio, plant, the tower—officially known as a "radar antenna test pattern fixture"—was built and delivered by Bliss within 6 months after award of contract. This project was sponsored by the USAF's Rome Air Development Center, Griffiss AFB, Rome, N.Y.

The fixture consists of a tiltable platform coupled to a stationary steel framework by a trunnion shaft, a gear segment, and a brake. Because it must be able to withstand wind velocities up to 80 mph, a great amount of weight—about 120,000 pounds—had to be built into it.

Precision Instrument

Despite this weight, the tower is actually a precision instrument. For example, the allowable deflection between the outside rim of the platform and the central pedestal on which the radar is mounted is only $\frac{1}{8}$ inch

Another design problem solved by Bliss was how to move the platform through 41 degrees of tilt, on only one axis, without drift or overshoot. This was done by a brake acting on the motor drive shaft with such precision that the angle of tilt is achieved within $1\frac{1}{2}$ minutes of arc.

As part of its contract, the Bliss Company designed and built all the drives, the trunnion shaft, the bearing and bearing blocks, the gear segment and brake, and a hydraulic snubber to damp out the fall of the platform in the event of a gear failure.

The entire structure is of steel, except for the main gear section, the brake arms, and the snubber cylinder, which are of ductile iron. **EE**

A GEODESIC radome is tested at GE's heavy military electronics department antenna development facility. Radome is erected on a new radar test tower designed and built to GE specifications by the E. W. Bliss Company. The tower, which consists of a tiltable platform coupled to a stationary steel framework, is used to determine the amount of deflection introduced into an incoming radar signal by various types of radomes used to house the radar antenna. Silhouetted in the translucent radome is reflector for the GE-built AN/FPS-7 high-power multibeam search radar.

Courtesy General Electric Company

THIS NIGHT-TIME photograph was made over Manhattan on January 9, 1958, at 11 p.m. with a Reconofax Camera which was developed by HRB-Singer, Inc. in 1951. The equipment was originally developed for the photo reconnaissance laboratory at Wright Patterson Air Force base. Subsequent sponsorship of work on Reconofax has been carried on by the Signal Corps.

Reconofax Makes Possible Detailed Aerial Night Photos

A detailed infrared photo taken with a system developed by HRB-Singer, Inc., has been declassified by the Office of Security Revue, Department of Defense, it was announced recently by Dr. J. L. McLucas, president of HRB-Singer, Inc., a subsidiary of The Singer Manufacturing Co.

A reconnaissance device, called Reconofax, made a picture of Manhattan at 11 p.m., January 9, 1958, from an altitude of 4,000 feet, which some expert sources have termed one of the most impressive photos of its kind ever seen. The so-called Manhattan Picture has been used for the last 2 years in military circles to demonstrate the capability of infrared for reconnaissance purposes.

Reconofax makes use of a scanning camera with an improved detector which is highly sensitive to infrared radiation. Radiation—or heat—differences between objects are recorded on film using a recording lamp. By utilizing a radio-relay system, the picture also can be developed almost simultaneously at a ground station.

Since all objects on the ground, including military targets, emit infrared, or heat, radiation, infrared provides an ideal means of producing night photographs for reconnaissance purposes. An advantage of an infrared system is its ability to detect radiation which is not visible, thus providing a possible means of camouflage detection.

In the Manhattan Picture, areas of considerable industrial activity, such as the power plants scattered throughout the city, are easily distinguished from areas of moderate activity—residential and commercial—and areas of slight activity, such as Central Park. Since the scanner system is heat-sensitive, the brightest objects in the photo are, of course, the hottest.

Reconofax's ability to resolve relatively small changes in temperature is shown by the clear definition of roads and paths in Central Park.

F. W. Howells, manager of the Singer Military Products Division, of which HRB-Singer, Inc., is a unit, points out that the declassification of Reconofax opens the door to numerous significant nonmilitary applications for the system.

Since different land and water surfaces emit varying degrees of heat, Reconofax can be used in hazardous areas for obtaining weather, oceanographic, and topographic data. For example, water temperature is said to be correlated with water depth. The contours of a shore line thus can be determined from the air.

Reconofax also can be used to photograph moving targets. With the scanner held stationary, the subject would scan itself. Applications of this nature might include traffic control, assembly line inspection, and burglar alarms.

Another possible variation is one in which both scanner and subject are stationary. In this case, the camera must provide a 2-dimensional scan in order to provide useful information. A typical application would be medical electronics. Since infections cause inflammation or heating of the skin, the film would show bright spots where infection exists. **EE**

System Locates Impact Point of Missile on Ocean Surface

The impact point of a ballistic missile or re-entry vehicle hitting the surface of the ocean can be located by underwater detection systems developed for the U. S. Navy by Bell Telephone Laboratories and installed by the Western Electric Company at both the Atlantic and Pacific Missile Ranges. The impact creates noise signals that are used to locate the spot where the missile hit the water.

Now in operation in conjunction with the Atlantic Missile Range, these underwater detection systems are aiding recovery teams in finding and retrieving missile nose cones after their space flights.

Several missile-impact locating systems (MILS) stations have been established, including one on the British island of Ascension. Similar stations have been set up or are being constructed on islands in the Pacific for the Pacific Missile Range.

Two types of acoustic systems are used in locating the missile impact point. One is a surface-impact system and the other is a SOFAR (Sound Fixing and Ranging) bomb method.

The surface-impact system is used for detecting and locating the sound of a missile actually striking the ocean's surface. This system uses six hydrophones, or underwater sound receivers, installed on the ocean floor and connected by a special cable to the shore station. Five of the hydrophones are located in the shape of a pentagon with the sixth receiver in the center. Information from at least three of the six hydrophones is needed to obtain an "acoustic fix." This provides an accurate "fix" over a restricted target area.

In the SOFAR method, a bomb is ejected from the missile and exploded underwater in the vicinity of the impact point. The sound of the exploding bomb is detected and measured to determine the area of impact. With SOFAR systems, detection is possible at distances of several thousand miles.

For the SOFAR detection method, a series of hydrophones, generally located in pairs are spaced about a large area and connected to shore stations by submarine cables. Electronic equipment at the shore stations records the signals from the hydrophones when the sound waves generated by the explosion of the SOFAR bomb are received. Trained operators at the shore installations are able to use the time differences of the sound arrivals at different hydrophones to obtain an acoustic fix that establishes the spot where the sound originated.

An operator must select the pairs of hydrophones to use for his calculations. The operator obtains the time of the signal arrival by each hydrophone in the various pairs of hydrophones he has selected. By subtraction this gives him a time difference between any two hyrophones. Since the location of the hydrophones and the velocity of sound in water at each location are known factors, the operator is able to convert time difference into distance difference by multiplying the time difference by the average velocity of sound for the combination of two hydrophones. Then he determines the acoustic fix by locating the intersection of two or more distance-difference lines on previously prepared charts.

By combining data from various stations in the Atlantic Missile Range, it is possible to obtain acoustic fixes on impacts throughout the range.

The detection system also serves as a navigation aid to recovery vessels. Prior to a missile launching, the ship drops SOFAR bombs and uses the time of the signal arrival at the hydrophones to determine its exact position in relation to the expected impact point of the missile.

To arrive at an acoustic fix it is necessary to know the speed with which sound travels through water at the location of each hydrophone. This velocity of sound at any given point in the ocean is a

function of temperatures, pressure, and salinity.

To check velocity and other factors in the Atlantic Ocean, a 3-month calibration operation was conducted during 1959 by personnel from Bell Telephone Laboratories, the Western Electric Company, and the U. S. Navy. Some 1,500 explosive charges were dropped in the ocean range areas to simulate the conditions of a missile-locating operation. By knowing the explosion time and position of these charges it was possible to check the accuracy of the underwater detection systems and provide data for the operators' use in determining acoustic fixes.

Although an operator at the missile-impact-locating station plots the acoustic fix on his charts, a more exact calculation is obtained by using a computer. Arrival time data from the Atlantic shore stations are sent to Patrick Air Force Base, Fla., and relayed to Winston-Salem, N. C., where the information is fed into a computer at Western Electric's plant. Precise determination of the impact point is furnished by this operation.

The underwater systems development department of Bell Telephone Laboratories at Whippany, N. J., developed the detection systems. Equipment for the system is furnished and installed by Western Electric's plant in Winston-Salem. EE

Unique System Cools Generator Stator Coils

A fully supercharged steam turbine–generator which utilizes a unique conductor cooling system in the generator stator has been developed at Allis-Chalmers Manufacturing Co., Milwaukee, Wis. Copper coil strands in the stator are transposed around a total of 6,000 feet of rectangular stainless tubing. Hydrogen gas passes through the tubing at velocities up to 10,000 feet per minute, transferring heat from the stator coils, keeping them at desirable temperatures.

Temperature requirements in the stator have always been a limiting factor in the capacity of conventional turbine–generators. In conventional units, cooling is difficult because the heat has to travel through a thick insulation wall.

With the new Allis-Chalmers generators, however, cooling tubes are an integral part of the stator coils. This conductor cooling technique permits greater kilowatt capability without increasing the physical size of the generator—an especially important development for power plants which must increase output but which are limited in space.

Removing heat by using cold gas within the major insulation of current-carrying conductors is an old idea, but it was never applied successfully to turbine–generators until Allis-Chalmers developed the prototype of its fully supercharged units in 1951.

Hydrogen was selected as the coolant because of its superior heat transfer characteristics. Since it is the lightest gas known, gas friction through the tubes is kept at a minimum.

For the hydrogen coolant path in the stator, engineers selected type *304* rectangular welded stainless steel tubing supplied by The Carpenter Steel Co., Alloy Tube Division, Union, N.J. This type tubing was specified for a number of reasons:

1. A nonmagnetic material was needed to avoid excessive heating caused by an extremely strong alternating magnetic field.
2. High resistance stainless tubing reduces eddy-current loss.
3. The inherent strength of stainless permits use of thin-walled tubing, allowing more room for copper in the stator coil and maximum possible gas space inside the tubes.
4. In fabricating the stator coils, thin-walled tubing is easier to bend.
5. The rectangular shape is required to conform with coil construction in the stator and to provide maximum surface for heat transfer.

Dimensions of the tubing are specified to suit requirements of the coils. For a typical 3,600-rpm generator, a total of 288 tubes are required. Each tube for this machine is 250 inches long.

The mass flow of hydrogen through the tubes varies with absolute pressure, which ranges from 1 to 4 atmospheres depending on cooling requirements. Operating temperatures vary over a range from 40 to 130 C. Gas pressure within the tubes is essentially balanced by external pressure.

EE

New Process Gives Larger, Squarer TV Picture

A method of manufacturing television picture bulbs which "squares a circle" to give a larger, clearer picture area was announced recently by Kimble Glass Company, a subsidiary of Owens-Illinois.

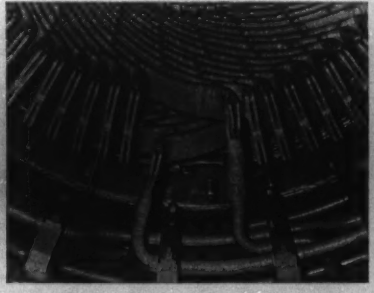
The new process is being used to produce a 23-inch bulb with a more rectangular face than the current 21-inch tube, but with the same 9¼-inch over-all tube depth. Sets containing the new 23-inch picture tube are no deeper than 21-inch sets.

Through the Kimble process, four accurate channels are formed in the bulb's yoke area along the path that the electron pattern will pass to the corners of the tube. This permits the corners—which have always been transmitted by the television station—to come through unclipped and with as high quality and contrast as other picture areas.

J. P. Kearney, Kimble vice-president, said that the new process is the result of Kimble efforts to overcome a problem that has plagued the television industry since its inception.

"The TV studio camera picks up a rectangular picture one third longer than it is high. The picture is transmitted as a complex electromagnetic signal, and is recreated as a rectangular pattern of electrons inside the television picture tube in the home receiver.

"This created the problem of a rectangular picture having to be forced



CROSS SECTION of single-turn armature coil (above, *left*) for fully supercharged generator shows arrangement of copper strands around rectangular stainless steel cooling ducts. A thin coating of silicone rubber separates the strands from the tubing. The outer insulating material is mica tape. Above, *right:* Only the end openings of rectangular stainless steel tubing are visible in assembled stator coils. When generator is in operation, hydrogen gas will circulate through tubing and remove heat from the coils. *Right:* After coils are assembled, stator for an Allis-Chalmers fully supercharged steam turbine–generator is inspected.

CHANNELED yoke area of new Kimble 23-inch television picture bulb (left) and its more rectangular shape are shown in comparison with a funnel from a regular 21-inch tube. The four flutes lead to the corners of the tube, permitting the flow of electrons to reach corner areas unhindered. This produces a larger, squarer picture without increasing set depth.

through a round opening in the 'deflection yoke' region of the tube. As a result, the corners of the picture were cut off, producing shadows," Mr. Kearney said.

It was explained that in addition to losing the corners of the transmitted pictures, the "corner clipping" resulted in electrons bouncing off the tube wall and randomly bombarding the viewing screen and reducing contrast.

The new channeled yoke area is being applied to a new 19-inch-square size in addition to 23-inch. The deflection angle of these tubes is 114 degrees, compared to the previous industry high of 110 degrees.

The bulb is designed to be used with a regular, separate safety plate rather than the bonded plate. **EE**

Commercial Thermoelectric Generator

A small (1-foot high), lightweight (10 pounds), automatic "power plant," with no moving parts, that can produce electricity for a year on $10 worth of ordinary propane gas and will keep running as long as the fuel supply lasts, has been placed on the market by General Instrument Corporation.

Believed by the company to be "the first practical thermoelectric generator actually to be made commercially available in the United States," the unit is designed as an ultra-reliable and unmanned source of power for radio communications, sea and air navigational aids, and industrial and scientific instrumentation in remote areas where other sources of electricity are not available or—as in the case of batteries—have a short life span and must be replaced or recharged.

Developed by General Instrument's Thermoelectric Division at Newark, N.J., the generator is expected to be priced at $500 or less in large-scale production quantities, it was stated, and will be available to both Government agencies and industry at large. Single "evaluation samples" are available at a price of approximately $5,000.

The new generator (which employs "Thermopiles" of semiconductor elements to convert the heat of the burning propane into electricity) produces 5 watts of power, steadily and continuously, for as long as the fuel supply lasts. It has been designed to run for approximately a year on a 200-pound tank (50 gallons) of propane gas, which sells commercially for about 5¢ a pound. By storing 1,000 pounds of propane gas with the generator, it could run unattended for 5 years, it was stated.

Projected uses of the generator include: unattended navigational beacons; radio communications relays in remote areas such as the Arctic; weather stations, where the generator could provide power to transmit automatically the data collected by the meteorological instruments; airport landing beacons and radio warning devices; automatic instrumentation for pipe lines, etc.

The thermoelectric power plant, which looks like a small cylinder only 12 inches high and 12 inches in diameter, has at its center a specially designed burner that burns the propane gas at a constant temperature and uses more than 85% of the heat content of the fuel. Surrounding the burner is a metal combustion chamber which captures the heat. Attached to each of the four sides of the combustion chamber are the thermopiles. The heat not used by the thermopiles is conducted directly to "heat rejection fins" made of aluminum, which form the outer shell of the whole unit and give it a star-like appearance.

The 5 watts of power produced, it was pointed out, is the same amount of electricity as is used to run the radio on the Pioneer V satellite, sending messages from hundreds of thousands of miles in outer space. It also is the same power as was produced by the experimental SNAP III atomic thermoelectric generator unveiled at the White House, Washington, D.C., in January 1959. **EE**

► **A THERMOELECTRIC** generator that automatically converts the heat of burning propane gas directly into electricity, has no moving parts, can produce electricity for approximately a year on $10 worth of fuel, and will keep running as long as the fuel supply lasts, was placed on the market recently by General Instrument Corporation. Propane fuel is fed into the generator (suspended sideways) where it burns steadily; the heat, captured in a combustion chamber, is converted by "thermopiles" of semiconductor elements directly into electricity, which lights small lamp.

"Fourth State of Matter" Works as Electronic Circuit

Scientists have successfully employed a "fourth state of matter," known as "gyro-electric plasma," to form a practical electronic circuit, it was reported recently by Dr. J. E. Hopson, Sperry Gyroscope Company research physicist.

An electric circuit so formed by the plasma has been made to operate as an electronic oscillator to generate radar energy at extremely high frequencies.

Plasma, which is neither liquid, gas, nor solid, consists of electrically charged parts of atoms which can both create and inter-react with electric and magnetic forces. Lightning in the sky, the active area of an electric arc, the sun's boiling surface, and earth's aurora borealis and ionosphere are familiar examples of plasma which exists in many natural forms in the universe.

"As we learn more about the characteristics of the electric circuits formed by plasma, it is conceivable that they may be used to replace or enhance operation of electronic devices that now use wires, capacitors, or other conventional circuit elements," Dr. Hopson said.

The man-made plasma, created by the Sperry scientists, was formed by aiming a slim beam of electrons through rarified hydrogen gas contained in an electromagnetic envelope. The beam electrons strike the hydrogen atoms with sufficient force to knock them apart and create a plasma of charged pieces of hydrogen atoms and electrons.

This beam-generated plasma has been called "gyro-electric plasma" because the charged particles move in a rotary manner analogous to the spin of a gyroscope.

Under specific conditions established in the experiment, the plasma behaves as an ordinary electric circuit which interacts with the electron beam and generates microwave radar energy. The plasma cir-

cuit couples into the electron beam which then serves as an antenna to convey the radar energy out of the plasma circuit for practical uses.

"This is the first experiment that demonstrates the specific conditions necessary for plasma to behave as an electric circuit for the generation of a given kind of microwave energy," said Dr. Hopson. "The experiments also provide basic details of plasma generated by an electron beam," he said.

"More knowledge gained in this branch of physics will help scientists understand several unexplained phenomena important to space sciences," he said.

Thus far, the research project has generated radar energy at frequencies ranging from 700 to 2,000 million cps, which is about 1,000 times the frequencies used in radio broadcasting. Sperry scientists indicated that by redesigning their apparatus it will be possible with current technology to generate frequencies more than 100 times higher, a range which approaches infrared waves.

The process revealed by this research project appears to be limited only by the magnetic field strengths and the interacting electronic structures available in current technology. With present technology, frequencies up to 280 billion cps can be generated.

The plasma research project was started by Sperry in 1957 when it was determined that certain oscillations observed in microwave tubes could not be accounted for satisfactorily. The Sperry Microwave Beam Plasma Research Laboratory was formed to conduct basic research into this little understood branch of physics. Since 1959, the major portion of this work has been sponsored by the Air Force Cambridge Research Center.

The project is purely a basic research program whose objectives are aimed at developing basic knowledge about plasma circuits and their microwave characteristics.

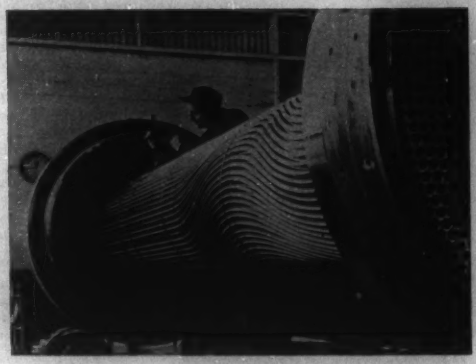
The early investigations were carried out by Sperry physicists Morris Ettenberg and Russell Targ. The present work is under the direction of Dr. C. C. Wang, with the assistance of Dr. Hopson and L. P. Levine, research physicists in the Electronic Tube Division of Sperry Gyroscope Company. EE

Sine Curve Put in Stainless Steel Tubing

More than 19 miles of stainless steel tubing will snake through three intermediate sodium heat exchangers being built for the Enrico Fermi Atomic Power Plant near Detroit to provide electricity to the Southeastern Michigan area.

The tubing, supplied by Allegheny Ludlum Steel Corporation, is inserted into heat exchangers being built by the Thermal Products Division of Alco Products, Inc., Dunkirk, N. Y., for Power Reactor Development Company, owners of the reactor.

These units are the largest sodium heat exchangers to be built to date. The shells are 88 inches in diameter of which 16 inches is shielding and nearly 31 feet long; one completely assembled heat exchanger weighs 130,000 pounds. Cost of the three exchangers has been estimated at about $1.75 million.



UNIQUE sine curve tubing is shown being installed in the Alco heat exchanger for the Enrico Fermi Atomic Power Plant. The stainless steel tubing was supplied by Allegheny Ludlum Steel Corporation to Alco Products, Inc., who put the sine curve in the tubing.

Heat is removed from the Fermi nuclear reactor by liquid sodium which circulates through the reactor core and blanket to the heat exchanger. A second sodium system transfers the heat from the exchanger to a steam generator, producing steam which turns a turbine directly connected to an electric generator.

Liquid sodium, according to Alco engineers, is a desirable heat transfer medium because it can maintain higher temperatures at lower pressures than water.

One of the unique features of the heat exchangers is a special sine curve which Alco puts into the type *304* stainless steel tubes. Each tube—approximately 18 feet long, with an OD of ⅞ inch and an 18-gauge minimum wall thickness—is bent cold on a machine especially designed by Alco.

The sine curve, a compound curve required because of space limitations and flow direction in the exchanger, accommodates differences in thermal expansion in the tubing. According to R. M. Church, chief project engineer at Alco-Dunkirk, U-shaped curves are common in heat exchangers utilizing ordinary fluids.

The other unique aspect of these units is that the tube bundle can be removed easily from its shell, thus facilitating maintenance work. It was explained that most exchanger units in nuclear application are of all-welded, integral construction, therefore they must be cut apart for repair. In addition to being removable, the bundles have a gasketed joint which separates the primary from secondary sodium fluids. Ten-inch-long springs act as load members for setting and sealing this joint.

High standards of cleanliness and noncontamination dictate the use of stainless steel in nuclear equipment. Its high strength-to-weight ratio also permits use of thinner walls, resulting in lower fabrication costs, it was stated.

Each of the three Alco heat exchangers is designed to transfer 489 million Btu per hour at flow rates of 12,500 gallons per minute. In an exchanger, primary sodium coolant flows by gravity from the reactor at a temperature of 900 F through the shell side of the unit to the pump from which it is returned to the reactor at 600 F. Secondary sodium from the steam generator is pumped at a temperature of 520 F through the downcomer in the exchanger, and through the 1,860 bowed tubes where it is heated to 820 F by the primary sodium. It then returns to the steam generator.

Three primary coolant loops and three secondary coolant loops will be connected to one reactor in the Fermi plant. It is scheduled for startup late in 1960. EE

28-Channel Airborne Miniature Recorder

A miniature airborne tape recording system, possibly the smallest 28-channel recording device ever designed for space, air, and industrial use, has been developed by the Leach Corp., Special Products Division.

It is already being employed by Sandia Corp. on high-speed tests connected with development work on non-nuclear components of nuclear warheads.

The new device, cylindrical in form with a diameter of 6¼ inches and length of 6½ inches, weighs less than 10 pounds. It was designed for data recording on recoverable missiles, satellites, rocket sleds, and torpedoes and also has applications in conventional aircraft.

The system, identified as model *I-119*, employs the carrier-erase technique using a 30-kc prerecorder carrier. Tape speed is 30 inches per second, providing 30 seconds of recording time. Frequency response is d-c to 5,000 cycles per second and system accuracy is approximately 5%.

It was stated that the device is capable of recording up to 26 channels of information, while two tracks (one for each Leach model *326* recorder) are used for timing signals from a built-in 10-kc oscillator.

The package includes 16 direct-coupled differential amplifiers, each having separate zero balance and gain adjustments. Each channel may be monitored at the recording head. Voltage regulation is provided for the electronic circuitry.

A 28-CHANNEL airborne tape recording system for air and space vehicles, possibly the smallest of its kind ever devised, has been developed by the Special Products Division of Leach Corp. It is built around two 24-ounce Leach recorders (upper photo) and weighs less than 10 pounds when fully encapsulated, as shown (lower right-hand corner) in comparison with a standard volt meter. The system, employing a carrier-erase technique using a 30-kc prerecorder carrier, also has applications in conventional aircraft.

Power requirements are 3 amperes d-c at 28 volts. The package is completely sealed and will withstand immersion in salt water for 10 hours at a pressure of 100 psi. Environmental specifications include 750 g's shock and 20 g's vibration (5 to 2,000 cycles per second). EE

Electronics Exhibit At New York Coliseum

The Institute of Radio Engineers (IRE) held its annual convention on March 21-24, 1960, at the Waldorf-Astoria Hotel and the Coliseum in New York City. There were more than 260 technical papers and 950 engineering exhibits of recent advances in the radio-electronics field.

Radio interrogation of the Pioneer V satellite, which at the time was speeding toward the 1.5-million-mile mark, signalled the start of the 4-day convention.

Some highlights of the exhibition were the following: a trouble-shooter that is able to spot defects in components, connectors, and cables automatically; a thermoelectric generator that delivers 100 watts; remote radio tuning device containing a silicon capacitor which makes it possible to tune car radio from the steering wheel; pressure transensor, an electronic device for the measurement of gastrointestinal pressures; sun-powered car, a 1912 Baker electric auto which has on its roof the largest single solar-cell panel ever assembled; a 100-tube digital computer the size of a cigarette pack made of tiny ceramic circuits called thermionic integrated micro-modules; television camera more than 1,000 times more sensitive than standard television cameras; and a strontium-90 powered automatic weather station.

In a paper delivered at a medical electronics session, Dr. H. H. Zinsser predicted a new kind of academic degree in a new profession—medical engineering. A new type of professional worker will have to be trained who is competent in both fields if real progress is to be made in bridging the gap between the biomedical sciences and the physical sciences. A new form of radar data processing was described by G. W. Preston, vice-president of General Atronics Corporation, Bala-Cynwyd, Pa. It is called the sequential probability ratio search radar and permits surveillance against bombers and ballistic missiles with at least 4 times the effectiveness of conventional radars. This is accomplished with a relatively small computer which analyzes the radar echoes and makes decisions at the earliest possible moment concerning the presence or absence of targets of interest. The output of the computer controls the scanning of the radar antenna; thus, coverage of a space can be accomplished many times faster than with conventional radars. EE

THIS is how television pictures would look when taken by the light of a thin crescent moon. Actually, the moonlight was simulated as part of General Electric's live demonstration at the IRE Show held at the New York Coliseum recently. In both cases, the subject is the same. In both cases, the camera settings and equipment are the same except for the camera pick-up tubes used. Picture at the top is taken with a standard broadcast tube and is about what the home viewer would see if his local station tried to telecast a moonlit scene without additional illumination. The other picture (at bottom) is taken with General Electric's new "see-in-the-dark" image orthicon (Z-5358).

NEW BOOKS

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ACCIDENT PREVENTION MANUAL FOR INDUSTRIAL OPERATIONS. Fourth edition. Published by the National Safety Council, Chicago 11, Ill., 1959. Various pagings, 6 by 9 inches, bound. $15. This revised edition contains new material on ionizing radiation, nondestructive testing, foundry operations, and elevators. Industrial safety and accident prevention, insurance, injury rates, and employee education are general considerations; specific plants and machinery such as boilers, materials handling equipment, power trucks, chains, ropes, wood working machinery, power presses, welding equipment, and power tools are then covered. The handling of materials—flammable, chemical, electrical, poisonous, and radioactive—is discussed, and in each case dangers and accident prevention measures are listed. Personal hygiene and protection are also explained.

ADVANCED ENGINEERING MATHEMATICS. By C. R. Wylie, Jr. Second edition. McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York 36, N. Y., 1960. 696 pages, 6¼ by 9¼ inches, bound. $9. An introduction to those branches of mathematics relevant to the engineer and the physicist, this edition contains a new chapter on determinants and matrices, and one on finite differences which includes the theory of orthogonal polynomials and the techniques of numerical analysis. Ordinary, linear, and simultaneous linear differential equations are covered thoroughly, and the section on partial differential equations includes solution by Laplace transform. Detailed treatment also is accorded the Fourier series, Bessel functions, Legendre polynomials, vector analysis, conformal mapping, and the theory of residues.

AVAILABLE ENERGY AND THE SECOND LAW ANALYSIS. By E. A. Bruges. Academic Press Inc., 111 Fifth Ave., New York 1, N. Y., 1959. 124 pages, 5½ by 8¼ inches, bound. $5.50. Introductory chapters deal with the first and second laws of thermodynamics and are preparatory for the rest of the book, since both laws are considered in the following analysis of available energy in the mixing of gases, vapours, and liquids; heat-exchangers; turboblowers; air compressors; gas dynamics; refrigeration; and power plants. The final chapters concern chemical changes, both theory and problems.

CATHODIC PROTECTION. By L. M. Applegate. McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York 36, N.Y., 1960. 229 pages, 6 by 9¼ inches, bound. $9. This practical book on the prevention of corrosion by electrolytic means, describes the making of the necessary field surveys and tests, the interpretation of test results, and the design and construction of the appropriate cathodic protection installations. Operational examples of the protection of such underground and submerged structures as pipelines, cables, aviation fuel tank and line systems, lock and dam gates, and ships in storage are given. Also included is an examination of the relationship of cathodic protection to static and power grounding systems.

DESIGN AND PERFORMANCE OF GAS TURBINE POWER PLANTS. (HIGH SPEED AERODYNAMICS AND JET PROPULSION, Volume XI). Edited by W. R. Hawthorne and W. T. Olson. Princeton University Press, Princeton, N. J., 1960. 563 pages, 6½ by 9½ inches, bound $15. This volume is designed to provide a basic source of present-day knowledge in the field of aircraft gas turbines. Combustion chamber design includes the basic requirements and processes of the system, experimental techniques, fuel injection, flame stabilization, mixing processes, fuels to be

used, and developmental considerations. The mechanics of materials and flutter problems are covered in the following section, and finally the various performance criteria which are used in the design of the engines are considered.

ELEKTRISCHE ISOLIERSTOFFE. By Alfred Imhof. Second edition. Orell Füssli Verlag, Zürich, Switzerland, 1949. 272 pages, 6½ by 9 inches, bound. 18.50 DM. This volume describes with scientific accuracy the installation, properties, manufacture, and treatment of insulating materials in electrical engineering. Particular emphasis has been put on practical use in constructing machines and equipment, and typical problems are worked out in detail. There are diagrams, drawings, and tables and electric stress formulas in an appendix.

FUNDAMENTALS OF ELECTRONICS. By E. N. Lurch. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1960. 631 pages, 6 by 9½ inches, bound. $8.25. This book is intended to provide a background in the fundamentals necessary for the study of the more specialized aspects of electronics, such as communications, microwaves, television, industrial electronics, and computer systems. It covers basic theory and practice taking into account recent advances in the areas of the vacuum tube and transistor electronics. Included are chapters on diodes and triodes, amplifiers, feedback, phase inversion, oscillators, modulation, detectors, audio components, and oscilloscopes.

GROSSE DAMPFKRAFTWERKE, PLANUNG, AUSFÜHRUNG UND BAU, Band I: KRAFTWERKSATLAS. Edited by Karl Schröder. Springer-Verlag, Berlin, West Germany, 1959. 1073 pages, 8 by 11 inches, bound. 192 DM. This first volume of a comprehensive work on large steam power stations is a "Power Station Atlas" containing concise, illustrated descriptions of 98 power stations all over the world. There are chapters on the Eddystone power plant and the Tennessee Valley Authority plants, as well as on power stations in Germany, Italy, and Argentina. Part II, when published, will deal systematically with the design and construction of power stations in general.

INDUSTRIAL ELECTRONICS AND CONTROL. By R. G. Kleoffler. Second edition. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1960. 540 pages, 6 by 9 inches, bound. $10. This practical survey for the nonspecialist begins with the theory of solid-state conduction and leads to the theory of rectification and amplification via the semiconductor. Current practice in such application as resistance welding and high-frequency heating, and recent developments such as solid-state thyratrons, cryotrons, and cold cathode vacuum tubes are covered. There is new material on semiconductors, magnetic amplifiers, computers, electronic measurements, and servomechanisms.

INDUSTRIAL INSTRUMENT SERVICING HANDBOOK. By G. C. Carroll. McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York 36, N. Y., 1960. Various pagings, 6½ by 9½ inches, bound. $16. The servicing and maintenance of more than 50 types of modern industrial process measuring and control instruments are detailed in this work, together with the principles of operation and complete calibration instructions for each. Instruments for gas analysis, for measuring pressure, fluid velocity, liquid level, temperature, viscosity, and specific gravity, and for the measurement and control of mechanical speeds are included. There is also a detailed chapter on the organization and staffing of an instrument maintenance department, and a precise tabulation of thermocouple temperature–millivolt equivalents.

INDUSTRIAL THERMAL INSULATION. By A. C. Wilson. McGraw-Hill Book Company, 330 W. 42nd St., New York 36, N. Y., 1959. 295 pages, 6¼ by 9¼ inches, bound. $9. Insulation for piping, equipment, and structures used by American industry in the temperature ranges between the boiling point of water and 2,000 F, and below the freezing point of water has been the object of recent research. This book deals specifically with heat transfer, calculation and interpretation of heat losses, and methods of application within these ranges. A large part of the book pertains to specifications for the insulation of hot piping and equipment; insulation of hot surfaces and application methods and specifications for low-temperature insulation are outlined. An appendix contains abbreviations, definitions, and terms, with tables and charts.

KONSTRUKTSIYA ELEKTRICHESKIKH MASHIN. By A. E. Alekseev. Second edition. Gosudarstvennoe Energeticheskoe Izdatelstvo, Moscow, USSR., 1958. 427 pages, 8½ by 10½ inches, bound. Price not given. Dealing with the fundamentals of the design of basic types of mass-produced electric motors. This edition pays considerable attention to cooling problems and the need for increased durability and maximum service. The book includes advanced designs of Russian and foreign units, and discusses methods of thermal analysis of sealed air-cooled motors.

MASERS. By Gordon Troup. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1959. 168 pages, 4¼ by 7 inches, bound. $2.75. A discussion of the stimulated emission process is followed by a brief outline of methods used to obtain the conditions necessary for amplification. The effects of various physical processes upon amplifier efficiency, and upon the effective frequency response of a molecular transition used to amplify, are described. The book goes on to give derivations of the gain, bandwidth, and noise factor of the traveling-wave line type of stimulated emission amplifier, and of the resonant cavity type of amplifier.

MATERIALS AND TECHNIQUES FOR ELECTRON TUBES. By W. H. Kohl. Reinhold Publishing Corporation, 430 Park Ave., New York 22, N. Y., 1960. 638 pages, 6¼ by 9¼ inches, bound. $16.50. This completely rewritten version of "Materials Technology for Electron Tubes," published in 1957, covers the composition, properties, and behavior of the materials used in electron tubes, and the techniques for assembling these materials. The materials discussed include glass, ceramics, mica, carbon, and graphite; base metals such as iron, steel, and copper and their alloys; and rare metals such as nickel, silver, platinum, molybdenum, and tantalum. The assembly techniques covered include metal brazing, and glass-metal and ceramic-metal sealing.

MICROWAVE DATA TABLES. By A. E. Booth. Iliffe & Sons Ltd., London, England, 1959. 61 pages, 7¾ by 10¼ inches, bound. £1.7.6. The 26 tables included evaluate basic relationships of frequency, guide and free-space wavelength, standing-wave ratio, voltage and power reflection coefficient, and the decibel. It is intended for waveguide engineers and for those concerned with high-frequency transmission lines of the coaxial and similar types. Guide wave-length tables are given for nine sizes of rectangular waveguide and two sizes of circular waveguide. Voltage standing-wave ratio and frequency are given to 3 decimal places, and decibels to 2 decimal places; the dependent variable is usually given to 4-figure accuracy.

NUCLEAR RADIATION ENGINEERING. By F. W. Hutchinson. The Ronald Press Company, 15 E. 26th St., New York 10, N. Y., 1960. 155 pages, 6¼ by 9¼ inches, bound. $6. The fundamentals of atomic structure, the source of nuclear energy, and the principles of radioactivity are presented for the growing number of administrators who must be technically informed in their dealings with nuclear scientists and engineers. In serving as a primer for those who must speak the language and understand the problems of atomic science, it explains the atomic and nuclear causes of radioactivity, the kinds of radioactivity, the energy release associated with the process of radioactive disintegration. These areas, rather than reactor engineering, are of immediate concern to executives and supervisors of nuclear engineers. A dictionary of atomic and nuclear terms and phrases is included.

AN OUTLINE OF UNITED STATES PATENT LAW. By R. E. Brink and others. Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y., 1959. 280 pages, 6 by 9¼ inches, bound. $7.50. This book combines in logical sequence the material related to obtaining and enforcing a patent which is included in the Rules of Practice of the United States Patent Office in Patent Cases, Title 35 of the United States Code, and the Manual of Patent Examining Procedure. Presented in outline form are the procedures of preparing a patent application, filing it, the internal and external reviews of decision, the course of interference, and the rights granted under a patent. In separate appendices, Title 35 and the Rules of Practice are included in their entirety, with a list of citations and a note on foreign practice and rights.

Library Services

ENGINEERING Societies Library books, except bibliographies, handbooks, and other reference publications, may be borrowed by mail by AIEE members for a small handling charge. The Library also prepares bibliographies, maintains search and translation services, and can supply a photoprint or a microfilm copy of any item in its collection. Address inquiries to R. H. Phelps, Director, Engineering Societies Library, 29 W 39 St., New York 18, N. Y.

POWER STATION ENGINEERING AND ECONOMY. By B. G. A. Skrotzki and W. A. Vopat. McGraw-Hill Book Company, 330 W. 42nd St., New York 36, N. Y., 1960. 751 pages, 6¼ by 9¼ inches, bound. $12.50. This retitled second edition of the authors' "Applied Energy Conversion" is virtually a new book, although it again stresses the study of the power plant as an integrated engineering system. Both thermal and water power stations are covered, with emphasis on the steam plant. Among the recent advances included are: nuclear energy in power production, gas turbine plants, modern systems of water conditioning, thermoelectric generators, solar energy, and fuel cells. Since the system concept is considered basic, system problems on station energy balances are plentiful. Other features include a complete study of power plant economy, an extensive discussion of supercritical steam cycles and large capacity steam turbines, and extensive problem work on heat balance.

RADIOISOTOPE TECHNIQUES. By R. T. Overman and H. M. Clark. McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York 36, N. Y., 1960. 476 pages, 6¼ by 9½ inches, bound. $10. This is a presentation of the underlying theory and principles, and the handling and measurement techniques involved in laboratory use of radioactive materials. Discussions in this vein relative to the detection of radiation, errors in radioactivity measurements, the preparation of radioactive sources, characterizations of radiation, radiochemical separation methods, and applications of radioisotopes are given. Radiological safety is emphasized throughout and also treated in a separate chapter. Illustrative experiments and problems are included.

REACTIVE METALS. (METALLURGICAL SOCIETY CONFERENCE, Volume 2) Edited by W. R. Clough. Interscience Publishers, 250 Fifth Ave., New York 1, N. Y., 1959. 610 pages, 6¼ by 9¼ inches, bound. $15. Papers in this volume cover nuclear properties and applications, interstitial effects, temperature effects, phase relationships, melting and refining methods, powder techniques, and the processing and fabrication of reactive metals. Some articles deal with procedures applicable to several metals, such as those on consumable electrode and electron beam melting, casting, slip casting, powder metallurgy, and the microgravimetric sorption method; some apply to only one metal and its individual properties. A wide range of types of metals is covered. The papers constitute the Proceedings of the Third Annual Conference sponsored by Niagara Frontier Section in co-operation with the Metallurgical Society of AIME.

RESISTANCE AND RESISTORS. By C. L. Wellard. McGraw-Hill Book Company, Inc., 330 42nd St., New York 36, N. Y., 1960. 264

pages, 6¼ by 9¼ inches, bound. $8.50. The first part of this book describes the concepts, theory, materials, and measurements of electrical resistance, and discusses in general terms the basic construction, characteristics, classification, nomenclature, specifications, and testing procedures of resistors in electronic circuitry. The major part of the book examines closely the specifications, characteristics, and applications of a wide range of types of resistors, including high, low, and medium power; wire wound and nonwire wound; general purpose, precision, or variable; and thermistors, varistors, potentiometers, attenuators, and special resistor products

SOLUTIONS TO PROFESSIONAL ENGINEER EXAMINATIONS, NEW YORK STATE. (BASIC ENGINEERING SCIENCES, Part II). By William Glendinning. Published by the author, 5123 Bell Boulevard, Bayside, N. Y., 145 pages, 8½ by 11 inches, paper. $3.50. Here are detailed solutions and answers to problems in basic mechanics and machine design, fluid mechanics and hydraulic machinery, thermodynamics and heat transfer, and electrical principles and equipment. The problems included were selected from Examinations in Professional Engineering, Part II, of the New York State Board of Examiners, over the past 14 years. The publication is the outgrowth of teaching review courses conducted over the past 15 years by the American Society of Mechanical Engineers and AIEE in the Metropolitan area to assist engineers preparing for P.E. examinations.

STRUCTURE AND PROPERTIES OF THIN FILMS (PROCEEDINGS OF AN INTERNATIONAL CONFERENCE HELD AT BOLTON LANDING, NEW YORK, ON SEPTEMBER 9-11, 1959). Edited by C. A. Neugebauer and others. John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1959. 561 pages, 8¾ by 11½ inches, bound. $15. Review papers in this volume contribute to the areas of preparation, growth, and structure of thin films, and their mechanical, electrical, optical and magnetic properties. A review of processes occurring at the metal surface also is given. Research papers present basic problems in physics and chemistry, concentrating on ferromagnetism in very small specimens, the nature of chemisorption, and the effects of small dimensions on various properties. The use of thin films to obtain information about the bulk properties of matter, the investigation of properties of thin films which vary from properties of the same material in bulk form, the growth and characterization of thin films, surface chemistry, and the theory of surfaces are the fields covered.

SYMPOSIUM ON ELECTROLESS NICKEL PLATING. Published as ASTM Special Technical Publication No. 265, by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., 1959. 67 pages, 6¼ by 9¼ inches, bound. $2.50. Six American papers on practical and theoretical aspects of the catalytic deposition of nickel-phosphorous alloys by chemical reduction in aqueous solution. Topics covered include the history of the electroless plating process, the chemical reactions involved and the characteristics of the resulting deposits, process procedures, the advantages and limitations and applications of the process, and methods of testing the solutions used. Included also are an examination of patents in the field, and a bibliography of 136 references.

TELEMETERING SYSTEMS. By P. A. Borden and W. J. Mayo-Wells. Reinhold Publishing Corporation. 430 Park Ave., New York 22, N. Y., 1959. 349 pages, 6¼ by 9¼ inches, bound. $8.50. Here are presented the practical aspects and possibilities of both stationary and mobile telemetering. The latter phase, now so important in rocketry, is entirely new to this edition and is based on information in telemetering used by weapon research programs which was hitherto classified. The authors stress the similarities between the two methods of telemetering in order to point out their increasing mutual dependencies in regard to practice and techniques. The types and principles of various systems are explained: current system, voltage system, a-c and d-c position systems, and impulse systems. Pickups and channels are included, as well as the selection, application, co-ordination, reading, computing, and integrating of the systems.

TECHNISCHER STRAHLENSCHUTZ. By Thomas Jaeger. Verlag Karl Thiemig, Munich, West Germany, 1959. 192 pages, 5¼ by 8 inches, paper. 8.60 DM. A symposium of previous articles by the author published in the German periodical *Atomkernenergie*. The first part of the book deals with the physical basis of γ- and neutron-radiation protection, calculation methods for the attenuation of radiation, and with concrete, in particular, as a material for radiation protection. The second part covers the disposal of radioactive waste material. There is a bibliography of 200 references.

TECHNICAL LITERATURE

The following recently issued technical literature may be of interest to readers of *Electrical Engineering*. All inquiries should be addressed to the issuers.

TABULATION OF DATA ON RECEIVING TUBES. This tabulation of data on receiving tubes currently in use has been prepared as part of the National Bureau of Standards Electron Devices Data Service which attempts to obtain and maintain a file of data on all electron devices, i.e., tubes, transistors, diodes, etc., manufactured in the United States and abroad. In an effort to make this service more readily available to engineers applying electronics in laboratories throughout the country, it was decided to develop a method of tabulating the essential information on these devices in handbook form. A tabulation of receiving-type electron tubes with some characteristics of each type has been prepared in the form of two major listings: a numerical listing in which the tubes are arranged by type number, and a characteristic listing in which the tubes are arranged by tube type and further ordered on the basis of one or two parameters. The tabulation is accompanied by a listing of similar tube types and basing diagrams for the listed tubes. This 110-page Handbook 68 may be ordered from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for $1.

HANDBOOK OF ELECTRONIC TABLES AND FORMULAS. Especially prepared to meet the needs of electronic technicians, engineers, students, and hobbyists, this reference book contains tables, charts, formulas, and laws essential for all who work in electronics. Five sections include: Formulas and Laws of Electronics, Constants, Standards, Symbols, Codes, Service and Installation Data, Miscellaneous Data. A full-color 6-page fold-out contains a frequency spectrum chart based on latest 1959 Federal Communications Commission allocations. It is available from Howard W. Sams & Co., Inc., Indianapolis 6, Ind. Catalog No. HTF-1, 134 pages, price $2.95.

ZENER DIODE HANDBOOK. This circuit design book contains an extensive introduction to semiconductor theory and reverse breakdown characteristics of these voltage regulating devices, plus chapters on audio and r-f applications, a-c applications, d-c applications, and computer and instrumentation applications. It is fully illustrated with circuits, graphs, and tables to describe the devices in detail. It may be ordered from International Rectifier Corporation, El Segundo, Calif., $2 per copy.

DEKATRON HANDBOOK. Dealing with dekatrons, digitrons, trochotrons, and other related items, this 36-page handbook and circuitry manual covers a complete line of cold cathode counting tubes. In the booklet will be found specifications, applications, and numerous circuit diagrams and design criteria on all counting tubes offered by Baird-Atomic. The manual may be obtained for $1 by writing to Dekatron Handbook Section, Baird-Atomic, Inc., 33 University Road, Cambridge, Mass.

AUDIO DESIGNERS HANDBOOK. This 55-page booklet contains comprehensive audio design information and an up-to-date collection of amplifier circuits for use by design engineers and advanced "audiophiles." It also features the first appearance in print of a newly developed, high-gain, phase-splitter circuit, and a low-voltage high-current output stage. The handbook contains treatments of over-all requirements of monophonic and stereophonic systems, features of the ideal amplifier, amplifier performance criteria, the output stage, phase-splitter stage, voltage amplifier stage, preamplifier stage, and power supply. Fourteen pages of complete schematics of monophonic and stereophonic preamplifiers illustrate the range of design possibilities available to the equipment designer. They also indicate how the design engineer may utilize most effectively Amperex audio tubes which are listed according to function and basic specifications. Copies may be obtained for $1.50 from Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L. I., N.Y.

INSTRUMENTATION ABSTRACTS. A new abstracting service inaugurated in January 1960 includes articles dealing with instruments and instrumental methods for determining chemical composition and product quality; covering instrumental measurement of physical qualities; and dealing with instrumentation for process control. American and foreign journal articles, papers presented at technical meetings, patents, and books are covered. Articles will be abstracted soon after they become available and abstracts distributed weekly. A total of 70 journals will be searched regularly and it is estimated that there will be at least 50 abstracts per week. The cost of subscription to the service is $50 per month or $600 per year for one set of abstracts. Additional sets sent to the same address are $20 per month each. Instrumentation Abstracts, 80 E. Jackson Blvd., Chicago 4, Ill.

ELECTRICAL EQUIPMENT. The 47th National Safety Council Transactions, Vol. 10 contains the following articles: Maintenance of Explosion-Proof Motors; Safety Inspection of Machinery by Use of Ultrasonics; Purchase and Design of Safe Electrical Test Equipment; How Important Is Safe Handling in the Heavy Electrical Industry?; Special and Unusual Accident Problems in the Electrical Equipment Manufacturing Industry. It may be ordered from National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill. Stock No. 022.29—10; price 40¢.

SUPPLEMENTS TO ASTM STANDARDS. Each part-supplement brings up-to-date the corresponding part of the 1958 Book of Standards by including new and revised standards adopted in 1959. The book and supplements contain over 2,600 standard specifications, methods of test, recommended practices, and definitions of terms for materials. Among the supplements are the following: *Part 2. Non-Ferrous Metals Specifications and Electronic Materials; Part 3. Methods of Testing Metals; Part 7. Petroleum Products, Lubricants, Tank Measurement, Engine Tests; Part 9. Plastics, Electrical Insulation, Rubber, Carbon Black.* These supplements may be obtained from the American Society for Testing Materials (ASTM), 1916 Race St., Philadelphia 3, Pa., at $4 per part.

ARI STANDARD. A new standard, *Sealed Refrigerant Compressors and Condensing Units, 20 Horsepower and Smaller* 515-60, replaces ARI standard 320-56 which will be withdrawn from circulation. Covered under the new document which is intended for the guidance of the industry, including manufacturers, distributors, installers, contractors, and users, are sealed electric-motor-driven refrigerant compressors, as well as air-cooled, evaporatively-cooled, and water-cooled sealed condensing units 20 hp (nominal) and under. It applies to sealed refrigerant compressors and condensing units using Refrigerants 12 and 22. The standard is available from Air-Conditioning and Refrigeration Institute (ARI), 1346 Connecticut Ave., N. W., Washington 6, D. C., at 25¢ per copy.

Wear Your ◆ AIEE Badge

Meet me in St. Louis . . .

Foresight founded St. Louis, Missouri, as a French fur-trading post in 1764, and helped it grow to the nation's eighth largest city . . . to become a manufacturing center for 3,300 different products while remaining the nation's largest raw fur market.

Foresight on the part of local electric utilities and 18 trunk line railroads has supplied this city's commerce, homes and industry with power and transportation to keep St. Louis growing.

Foresight has enabled Kerite Cable to serve the past and present needs of power, railroad and other industries with a high standard of dependability—a standard maintained since 1854. *And when tomorrow's problems occur, Kerite will already be ahead of them.*

KERITE CABLE

it's the **KERITE** *that makes the difference*

General Office—30 Church Street, New York 7, N. Y.

SALES OFFICES:
Albuquerque, Ardmore, Pa., Birmingham, Boston, Chicago, Cleveland, Denver, Glendale, Cal., Houston, Lake Wales, Fla., Portland, Ore., St. Louis, Salt Lake City, San Francisco, Seattle

WILL YOUR "GROUNDS" CARRY IT?

During seasons of electrical storms, a careful program of checking all ground connections may save your company serious outages and property damage. Nine tenths of industrial lightning damage is reported to be on vital electrical equipment—motors, generators, transformers. Experience shows that ground resistance does not remain constant. Tests should be made at least once a year, and high ground resistance corrected.

Do You Have This Information File on Grounding?

The James G. Biddle Co. File 25 is an excellent fund of information on grounding problems. It includes a Manual on Ground Resistance Testing, and Bulletins on "Grounding Electric Circuits Effectively" and "Grounding Principles and Practices Applied to Industrial Plants."

USE THE MEGGER® GROUND TESTER

To test ground connections, the easiest, quickest, and most dependable method is the use of the Megger Ground Tester with its own hand generator for current supply. Reading the resistance value is as easy as reading a voltmeter—directly in ohms. Only *one set of connections, one operation, without any calculations.* Each instrument is self-contained, rugged, and portable. Its cost is a small fraction of the savings resulting from adequate grounding protection.

Write for Ground Testing File 25-EE.

B1010

BIDDLE INSTRUMENTS

JAMES G. BIDDLE CO.

Electrical & Speed Measuring Instruments

1315 ARCH STREET • PHILADELPHIA 7, PA.

New & Improved Products

(Continued from page 20A)

Prefabricated Antenna System . . .

A 40-foot antenna system has been especially designed for colleges and universities for advanced studies in radio astronomy and satellite communication. This student do-it-yourself kit is to provide a low-priced, high-precision component for organizations engaged in the study of interstellar space characteristics and the training of radio antronomers. The kits will include a variety of units from a simple reflector on a fixed mount to a manually controlled assembly with precision servo control and programmers for sidereal, solar, and lunar rates. *General Bronze Corp., GB Electronics Division, Hook Creek Blvd., Valley Stream, N.Y.*

Rescue Beacon . . .

An air-rescue radio beacon delivering an immediate alerting and locating signal from a downed aircraft will become standard equipment on all United Air Line's jet flights to Hawaii. Each of the plane's six 25-person life rafts will contain this beacon. Operating on the international aircraft distress frequency of 121.5 mc the equipment is automatically released and activated upon immersion in either salt or fresh water and will continue to operate for 50 hours. *Granger Associates, 974 Commercial St., Palo Alto, Calif.*

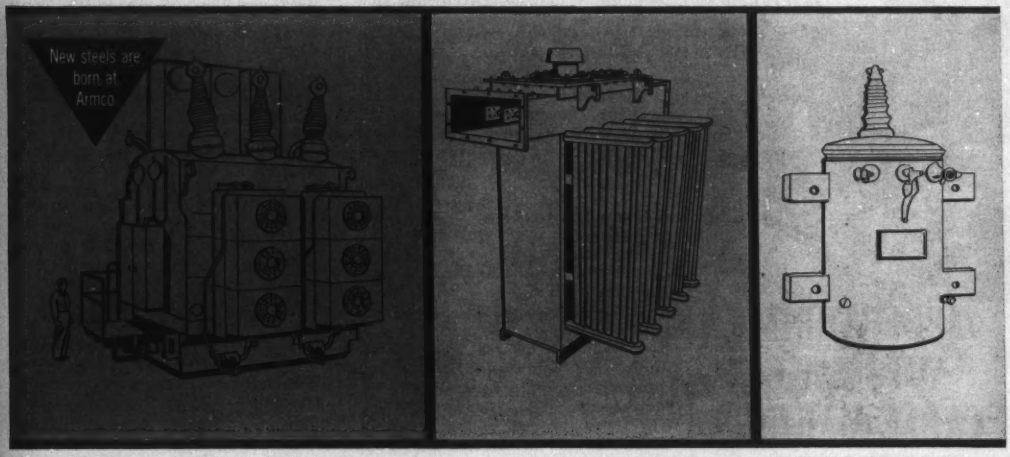
Electric Auto . . .

Remember the tiller-navigated glass fish bowl on wheels" your wealthy Aunt Nell once proudly drove down Main Street? Well, it's back again, but this time it looks like a Renault Dauphine, has semibucket-type seats, no-fade hydraulic brakes, and a top speed of 35 mph. With a maximum range of between 50 and 60 miles-per-battery charge, this simple, maintenance-free vehicle called the Henney Kilowatt will provide low-cost short-hop transportation. *Henney Motor Co., Division of Eureka Williams Corp., Canastota, N.Y.*

Support the New United Engineering Center

ARMCO STEELS / for electrical and electronic equipment

Transform Electrical Energy More Efficiently, at Lower Cost With Armco Oriented Electrical Steels



Transformers, ranging from 300,000 KVA power giants to distribution and special units handling as little as 5 KVA, can operate more efficiently and cost less with cores of Armco Oriented Electrical Steels. Their combination of low core loss and high permeability at high inductions offers unique design advantages.

NEW ARMCO M-5

Opportunities to reduce transformer size and weight or step-up operating efficiency are expanded by Armco's new Oriented M-5 grade. It has a maximum core loss of only .58 watts/lb. at 60 cycles and 15 kilogausses, and has materially higher permeability at high inductions than oriented silicon steels previously available.

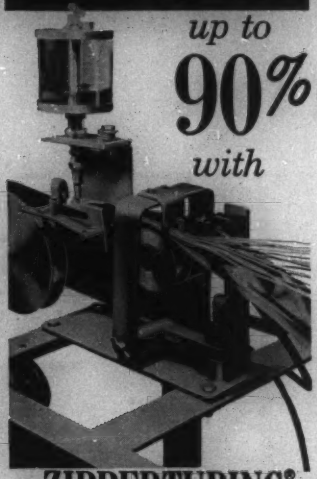
With all grades of Armco Oriented Electrical Steel, M-5 through M-8, you also get the plus values of properties fully developed at the mill; excellent lamination factors, and thin, high-resistivity surface insulation. In addition, to assist you in utilizing their advantages most effectively, Armco has recently published its fifth edition of the design manual, "Armco Oriented Electrical Steels." It contains complete information, plus 40 pages of graphical data, on magnetic properties and design.

Make the cores of your power, distribution and high performance transformers of Armco Oriented Electrical Steels. They will help you meet the challenge of competition and rising costs. Write for catalog and complete information. Armco Steel Corporation, 1770 Curtis Street, Middletown, Ohio.

ARMCO STEEL

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

SAVE



up to 90% with

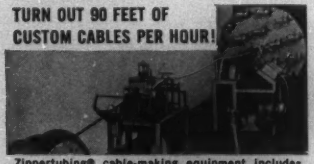
ZIPPERTUBING® AUTOMATIC CABLE-MAKING EQUIPMENT

1-STEP Cable Jacketing

Using the Zippertubing® automatic cable-jacketing machine, you can make cables in your own plant for just a fraction of your present cost. Inexperienced men can handle this machine which is available on lease only.

Wide choice of Zippertubing® materials includes laminated copper, aluminum or conetic steel in combination with vinyl, Mylar or fiberglass.

TURN OUT 90 FEET OF CUSTOM CABLES PER HOUR!



Zippertubing® cable-making equipment includes cable strander and jacketing machine compactly designed to require a minimum of floor space. Actual test records show almost unbelievable savings of 90% in labor costs alone!

Write for free literature and name of nearest field representative.

Patent and Patent Applied For

THE Zippertubing CO.

Industrial Notes...

Rotek Instrument Corp.
Cambridge, Mass. . .

Rotek Instrument Corporation has been formed to develop and manufacture high-precision transistorized instruments for electronic test and development laboratories. A wide range of product lines within several major areas of precision instrumentation is now under development by the new corporation. Stress is placed on achieving highest precision and ultimate reliability for the equipment, which is being designed to operate under wide environmental extremes, permitting field measurements with true laboratory accuracies. Rotek's offices are at 733 Concord Ave., Cambridge 38, Mass.

General Motors Corp.
Detroit, Mich. . .

General Motors Research Laboratories uses a unique test car to study driver reaction to different steering systems. Equipped with a mass of electrohydraulic servomechanisms, transducers, and computer devices, the car can create steering characteristics from "feather touch" to "driving like a truck." It also can simulate certain irregularities in steering and handling, such as the effects of wind gusts and changes in road surface. Designed and built by Cornell Aeronautical Laboratory, Inc. for General Motors, the car has a special steering system with no mechanical linkage between the steering wheel and the front wheels. The steering ratio can be varied automatically, so low that less than one turn will swing the front wheels to their turning limits, and so high that eight full turns are necessary. It also is possible to make the front wheels turn with just turning pressure on the steering wheel although the steering wheel itself doesn't move.

AMF
New York, N.Y. . .

Astronauts will be able to live for up to two weeks under conditions they may find in outer space without ever leaving the ground in a new training unit. Research and development work for this new space cabin simulator is being conducted by American Machine & Foundry Co. (AMF), Mechanics Research Division, 261 Madison Ave., New York 16, N. Y., under a contract from the U. S. Naval Training Device Center, Port Washington, N. Y. The AMF space cabin simulator will be equipped with the complex air conditioning and cabin pressurizing equipment necessary to keep astronauts alive at temperatures hundreds of degrees below zero and at zero gravity when the human body would be completely weightless. The simulator will make it possible to train astronauts in the operation of this equipment.

Electric Storage Battery Co.
Philadelphia, Pa. . .

An unusual, ready-to-ship spare-parts kit for the Exide line of vertical motor-generator chargers used with electric industrial truck and mine locomotive batteries contains parts that commonly need to be replaced after long use in electric motor equipment. The kit comprises a full set of brushes, two bearings, and a fuse in a clearly labeled corrugated package. There is a kit of parts to fit each of the 25 sizes of Exide vertical motor-generator chargers. Exide Industrial Division, The Electric Storage Battery Co., Rising Sun and Adams Ave., Philadelphia 20, Pa.

National Beryllia Corp.
North Bergen, N.J. . .

Completion of the nation's largest facility for research and production of beryllium oxide ceramics materials, used in missile, electronics, and nuclear applications, has been announced by National Beryllia Corp., North Bergen, N. J. The expansion of the company's plant and laboratories at Haskell, N. J., is said to represent a tripling of floor area and production capacity. The rapidly growing need for products with the unique combination of properties possessed by beryllium oxide, also known as beryllia necessitated the expansion.

Electro Scientific Industries
Portland, Oreg. . .

Electro-Measurements, Inc. has had its name changed to Electro Scientific Industries. The company is located at 7524 S. W. Macadam Ave., Portland 19, Oreg.

(Continued on page 30A)

Professional Engineering Directory

Professional Engineering Directory Card 1" or 2" 12 times $180.00

ELECTRICAL TESTING LABORATORIES, INC.
2 East End Avenue, New York 21, N. Y.
Electrical, Electronic, Environmental, Photometric and Chemical Laboratories
Testing, Research, Inspection and Certification

THE KULJIAN CORPORATION
Engineers • Constructors • Consultants
POWER PLANT SPECIALISTS
(Steam, Hydro, Diesel)
Utility • Industrial • Chemical
1200 NO. BROAD ST., PHILA. 21, PA.

MINER and MINER
Consulting Engineers
Incorporated
Greeley Colorado

INTERNATIONAL ENGINEERING COMPANY, INC.
Engineers
Investigations—Reports—Design
Procurement—Field Engineering
Domestic and Foreign
74 New Montgomery St.,
San Francisco 5, Calif.

MEASUREMENTS
A McGraw-Edison Div.
RESEARCH & MANUFACTURING ENGINEERS
Specialist in the Design and Development of Electronic Test Instruments
Boonton, N.J.

MULTI-AMP Division
MULTI-AMP ELECTRONIC CORPORATION
Designers • Engineers • Builders
Portable Electric Test Equipment
Field and Laboratory Instruments; Load Boxes
For low-voltage testing and calibrating of circuit breakers, protective and overload relays, reclosures, watthour meters, fuse links.
467 B Lehigh Ave. Union, N. J.

DE LEUW, CATHER & COMPANY
CONSULTING ENGINEERS
Public Transit — Subways
Traffic & Parking — Railroad Facilities
Expressways — Industrial Plants
Grade Separations — Municipal Works
Urban Renewal — Port Development
150 North Wacker Drive, Chicago 6
San Francisco Toronto Boston

BLACK & VEATCH
Consulting Engineers
Electricity—Water—Sewage—Gas
Industry Reports, Design,
Supervision of Construction,
Investigations, Valuation and Rates
1500 Meadow Lake Parkway
Kansas City 14, Missouri

JACKSON & MORELAND, INC.
Jackson & Moreland International, Inc.
ENGINEERS and CONSULTANTS
Electrical—Mechanical—Structural
Design and Supervision of Construction
-:- for -:-
Utility, Industrial and Atomic Projects
Surveys—Appraisals—Reports
Machine Design—Technical Publications
BOSTON WASHINGTON NEW YORK

HIGHLAND DESIGN INC.
William R. Spittal & Staff
Design, Development and Manufacture of Transformers, Chokes, Etc.
for the
Electronics, Industrial and Allied Fields
90 Magnolia Ave., Westbury, L.I., N.Y.
EDgewood 3-2933

CONSULT THIS DIRECTORY
when in need of specialized engineering service

SARGENT & LUNDY
ENGINEERS
Consultants to the Power Industry
STUDIES • DESIGN • SUPERVISION
140 South Dearborn Street, Chicago 3, Ill.

NEW SCAM® MAGNA-PLAC NAMEPLATE

Your systems' sentry, Scam De-Line annunciators, now offers a new MAGNA-PLAC nameplate which provides a full 10½" of engraving area—70% more than conventional nameplates.

MAGNA-PLAC gives engineers increased area to more accurately describe condition variations or to employ larger characters for greater visibility. MAGNA-PLAC is interchangeable with standard Scam nameplates and optionally available on De-Line units *without extra charge.*

Other De-Line features include side by side or stack mounting for practical, *economical* system expansion; a single plug-in relay for both normally open *or* normally closed contacts; and sequence options *after* installation.

Yes, continuous product improvements such as MAGNA-PLAC, flexible application, ruggedness and reliability are what make De-Line the engineer's annunciator.

Complete Monitoring Systems for Industry

SCAM® INSTRUMENT CORP.

Dept. C, 1811 W. Irving Park Rd., Chicago 13, Ill.

Representatives in Principal Cities

WRITE FOR MORE INFORMATION on De-Line MAGNA-PLAC. Just sign and attach coupon to company letterhead.

NAME _____

Industrial Notes

(*Continued from page 28A*)

Plastic Age Sales Mint Canyon, Calif. . .

Fiberglas street light globes that will not break or shatter are now being marketed by Plastic Age Sales, Inc., 14300 Davenport Rd., Mint Canyon, Calif., manufacturers of reinforced and acrylic plastics for home and industry. Developed in co-operation with a leading Southern California utility, the new Fiberglas globes can save up to $50,000 per year for city, county, or state governments in the time-consuming, costly replacement of broken street light globes. Made of a special modified polyester resin, reinforced with

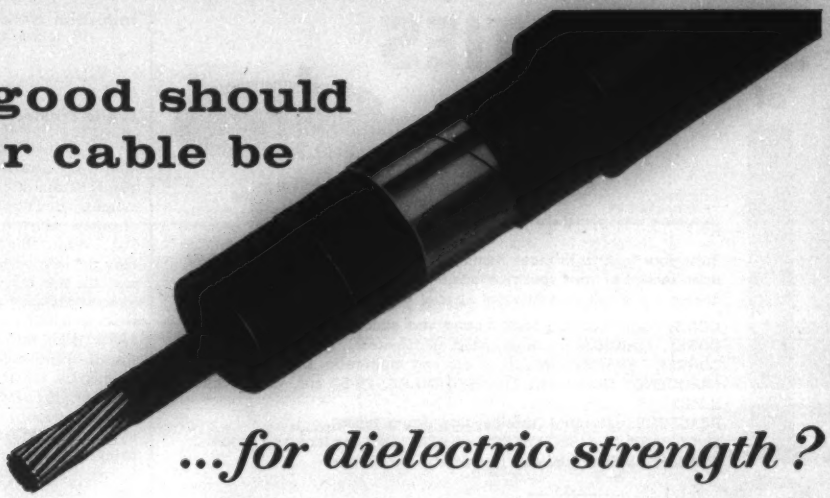
chopped Fiberglas, the globes will withstand objects propelled from a distance of less than 6 feet. Light transmission qualities are excellent and the globes are not affected by temperatures in the range of −20 to 350 F. Laboratory tests using 6,000- and 10,000-lumen lamps showed no deterioration. Ultraviolet and weatherometer tests indicated a 3- to 5-year life with no effects from sunlight or adverse weather. Dropping the globes from a 40 foot height did not crack or shatter them. The globes weigh less than 1/10 that of the present glass globes.

Keuffel & Esser Co. Hoboken, N. J. . .

Formation of a new K&E Optics and Metrology Division has been announced by Keuffel & Esser Co., 303 Adams St., Hoboken, N. J. The new division will specialize in the development and manufacture of optical, mechanical, and electronic systems and components for precise measurement of lengths and angles. The specialized division was created to serve industry and the military in the increasingly refined science of optics and metrology.

(*Continued on page 34A*)

how good should power cable be



...for dielectric strength?

At CIRCLE, the point is not how well specifications are met—but rather *how far they can be exceeded!* Take, for example, the well-known "double voltage test" as required by IPCEA-NEMA.

IPCEA-NEMA Performance Requirements

"6.5.3 After the sample has been immersed for at least one hour, it shall withstand for 5 minutes a test voltage which is twice the test voltage given in Table 12."

"6.5.4 . . . starting with the voltage at which the test described in 6.5.3 was made, the voltage shall be raised in steps of approximately 20 per cent of the immediately preceding voltage until failure occurs, the voltage to be kept constant at each step for 5 mintues."

"Circlesheath® Type RR Power Cable Performance"

The following table describes the performance of three samples of Circle butyl-insulated Type RR power cable.

CABLE SIZE	RATED VOLTAGE	DOUBLE AC TEST VOLTAGE	CIRCLE B'KDN VOLTAGE	MAXIMUM STRESS IN VOLTS PER MIL
2 AWG	5KV	28KV	48.3KV	454
1/0 AWG	5KV	28KV	40.3KV	356
500 MCM	5KV	31KV	44.6KV	307

A Circle power cable, subjected *for over two years* to a 250% overload of rated voltage in a *test still in process*, continues to meet all specified requirements.

A frequent sight at Circle is the checking of extruder operation by laboratory technicians. They are concerned with seeing that the quality they build into a cable in the lab is realized on the production line.

Turning out high-reliability power cable requires expert knowledge of compounds, absolute quality control—and men who *know enough* to produce the very best. Next time you specify power cable, ask for Circle—there's no finer made.

CIRCLE WIRE & CABLE
a subsidiary of
CERRO DE PASCO CORPORATION

RUBBER COVERED WIRE & CABLE • VARNISHED CAMBRIC CABLE •
PLASTIC INSULATED CABLE • NEOPRENE SHEATHED CABLE • CIRTUBE® EMT

SPECIALTIES of

CURRENT TRANSFORMERS (reduced 4 times actual size)

Take your pick from these items and we shall be glad to quote you upon receipt of your specifications.—Remember there is no set-up charge for small quantities of special constructions.

COILS, paper section, form wound and special constructions.
CORES, TOROIDAL, grain-oriented silicon-steel.
CURRENT TRANSFORMERS, single and multi-ratio, Donut type.
FREQUENCY DOUBLING TRANSFORMERS, 25-50 cps, 60-120 cps.
REACTORS, fixed, variable (VARI-HENRY).
REACTORS, saturable (toroidal and c-core types).
TAK-A-PART TRANSFORMERS and REACTORS for labs and schools.
TRANSFORMERS, toroidal, instrument and power.

MS Magnetic Specialties Inc.

SPECIALISTS IN CUSTOM-BUILT ELECTRO-MAGNETIC DEVICES
P.O. BOX 476, Dept. EG5, Trenton 3, N. J.

SYSTEMS ENGINEERS

ORDNANCE RESEARCH LABORATORY

ELECTRONICS ENGINEERS

CHALLENGING R&D OPPORTUNITIES

Fundamental and applied research in the fields of hydrodynamics, acoustics, electronics, network theory, servomechanisms, mechanics, information theory and noise reduction. Also design of electronic instrumentation for underwater ordnance and application of analogue and digital computers.

Opportunities for Graduate Study
Faculty Appointments for Qualified Applicants
Excellent Working and Living Conditions

Send Resume to

ARNOLD ADDISON, PERSONNEL DIRECTOR
ORDNANCE RESEARCH LABORATORY
THE PENNSYLVANIA STATE UNIVERSITY
BOX 30, UNIVERSITY PARK, PA.

Industrial Notes

(Continued from page 30A)

IBM White Plains, N.Y. . .

A miniature automatic assembly line is now turning out computer transistors at the rate of 1,800 an hour. The system, developed by International Business Machines Corp., 112 E. Post Rd., White Plains, N. Y., makes the tiny devices, which have become essential to the manufacture of most advanced data-processing equipment. The new machine is roughly five times faster than the semiautomated assembly of transistors now in general use. It has by far the highest production rate of the few existing automatic methods. Holding to tolerances as close as 0.0005 inch, the machine is able to produce transistors of greater uniformity than those made by previous methods.

Bausch & Lomb Optical Co. Rochester, N.Y. . .

A separate Military Products Division of Bausch & Lomb will work with both the Government and prime contractors on the development of items needed for the national defense program. The major objectives of the organization are to establish Bausch & Lomb as a research and manufacturing source for integrated optical-mechanical-electronic systems, to obtain contracts for the manufacture of such systems, and to develop improved optical solutions to problems which heretofore have been considered solely in the field of electronics.

United Air Lines Chicago, Ill. . .

A new electromechanical machine that produces an airline ticket in a single second has been placed in operation at one of the Chicago ticket offices of United Air Lines. Known as Ticketeer 202, the unit reduces ticket preparation time by as much as 75%. It was designed and developed by the airline and the Burroughs Corp. over a 3-year period. By midsummer, 84 will be installed at United's major ticket offices and airport terminals. To operate the machine, which is no larger than an office-type water cooler, agents merely insert a preselected matrix. The machine immediately produces a ticket imprinted with the origination and destination cities, the fare and transportation tax, class of service, and complete auditing information. The tickets are approved for interline use.

COME TO WESTINGHOUSE!

SILICON RECTIFIERS

		P. R. V.	Max. DC Current at T°C Resistive Load	Max. One Cycle 60 C.P.S. Surge Full Load	Max. Rev. Peak Current @ Max. Temp. & P.I.V.
LOW POWER RECT.	1N1217 SERIES	50-1000 V.	500 MA @ 110°C. AMB.	15 AMPS.	1.5 MA @ 150°C. JUNCTION
	1N1227 SERIES	50-1000 V.	1.6 A @ 140°C. CASE	15 AMPS.	
MEDIUM POWER RECT.	1N1341 SERIES	50-600 V.	6 A @ 150°C. CASE	160 AMPS.	10 MA @ 190°C. JUNCTION
	1N1199 SERIES	50-600 V.	12 A @ 150°C. CASE	200 AMPS.	
	1N1191 SERIES	50-600 V.	18 A @ 140°C. CASE	220 AMPS.	
	1N1183 SERIES	50-600 V.	35 A @ 140°C. CASE	220 AMPS.	
HIGH POWER RECT.	1N1396 SERIES	50-500 V.	70 A @ 150°C. CASE	1200 AMPS.	30 MA @ 190°C. JUNCTION
	1N1660 SERIES	50-500 V.	160 A @ 125°C. CASE	2000 AMPS.	40 MA @ 190°C. JUNCTION
	1N1670 SERIES	50-500 V.	240 A @ 125°C. CASE	3000 AMPS.	50 MA @ 190°C. JUNCTION
	439 SERIES	50-600 V.	240 A @ 125°C. CASE	3000 AMPS.	

GERMANIUM TRANSISTORS

	Class	Typical Operation			Maximum Ratings			
		I_{CBO} μa	h_{FE}	f mc/s	V_{CE} V	I_C ma	P_C mw	T_J °C
2N59	AUDIO-PNP	10	100	1.2	20	200	180	85
2N60	AUDIO-PNP	10	70	1.1	20	200	180	85
2N403	AUDIO-PNP	10	33	0.85	20	200	180	85
2N614	IF -PNP	3	5	3	20	150	125	85
2N616	IF -PNP	3	20	9	20	150	125	85
2N617	IF -PNP	3	14	7	20	150	125	85

SILICON POWER TRANSISTORS

	Type	h_{fe} or h_{FE}	fαmc	V_{CEX} Volts	I_C Amps	T_J °C
2N1015 SERIES—2 AMP.	NPN	10 (V_{CE}=4 V I_C=2 A)	ALPHA CUTOFF .300	30-200	7.5a	150
2N1016 SERIES—5 AMP.	NPN	10 (V_{CE}=4 V I_C=5 A)	ALPHA CUTOFF .300	30-200	7.5a	150

50 AMPERE SILICON "TRINISTOR"* CONTROLLED RECTIFIER

Breakover Voltage @ 125°C T_J	Reverse Blocking Voltage @ 125°C T_J	Turn-on Time	Turn-off Time
TYPICAL			
50-200 VOLTS	50-200 VOLTS	1.0 μ SEC.	15-20 μ SEC.

RECTIFIER ASSEMBLIES

Standard rectifier assemblies are available in all types of circuit configurations, and are designed for either forced air or natural convection cooling with a wide range of ratings. Nickel-plated copper plates and other materials used in these assemblies have been chosen to insure satisfactory performance in corrosive atmospheres and high ambient temperatures.

THERMOELECTRIC COOLING DEVICES

Two types are available in commercial quantities: WX814 (2.5 oz.) and WX816 (3.0 oz.). Both types measure about an inch and a half square and will find immediate application in cooling germanium transistors, infrared detectors, optical systems, mechanical and electric instruments, laboratory and portable medical equipment, and related fields where spot cooling below ambient is necessary.

INFRARED DETECTORS

Type	Noise Equivalent Power (NEP) Watts		Wave-length Response, Microns	Time Constant, μ SEC.	
	TYPICAL	LIMIT		TYPICAL	LIMIT
812	5×10^{-11}	10^{-10} MAX.	1-12	0.1	0.2 MAX.

The types listed are just a small sampling of the complete line which can be supplied in volume quantities for prompt deliveries.

digital computer engineers

circuit designers
logical designers
systems analysts
programmers

HUGHES in FULLERTON has immediate Research & Development openings for circuit designers, logical designers, programmers and analysts for the development of large scale information processing systems, including new general purpose and special purpose computers. Assignments exist in the following areas of specialization:

GENERAL PURPOSE COMPUTER SYSTEMS

- Microwave Carrier Logic
- Millimicrosecond Base-Band Logic
- Tunnel Diodes
- Evaporated Magnetic Components
- Micro-Electronic Techniques
- Transistor High-Speed Gating Techniques
- Solid State Circuits
- Core Memory and Buffers

ARMY/NAVY COMPUTER SYSTEMS

- Systems Analysis and Evaluation
- Operations Research
- Self-Test and Maintenance Engineering
- Logical Design
- Transistorized Digital Circuits
- Digital Memory Devices
- Advanced Displays
- Servomechanisms and Feedback Amplifier Design
- Digital Data Organization and Transmission
- Voice Communication and Modulation Techniques

HUGHES
HUGHES AIRCRAFT COMPANY
FULLERTON RESEARCH & DEVELOPMENT

For further information or interview appointment, visit, write or telephone (collect):
Mr. B. P. RAMSTACK
Hughes Aircraft Company
P.O. Box 2097
Fullerton 8, Orange County, California
Call: TRojan 1-4080, Ext. 3741

Trade Literature...

Plastics Table of Properties . . .

Shown are significant physical, electrical, chemical, and optical properties of nine thermoplastic materials. Materials covered are acrylics, acetate, butyrate, Teflon and Kel-F fluorocarbons, nylon, polyethylene, and vinyls. Data is compiled from test reports submitted by manufacturers. Properties shown include: tensile, impact, flexural, and compressive strength; resistance to sunlight, water, weak and strong acids, and alkalies; dielectric short-time strengths and constants; power factors; machining qualities, hardness, flexibility, and thermal properties. *Cadillac Plastic & Chemical Co., 15111 Second Ave., Detroit 3, Mich.*

Technical Films Catalog . . .

Specialized motion pictures about new products, advanced industrial processes, and cost-saving techniques are listed in a revised edition of the business and professional film catalog recently published by Modern Talking Picture Service. The films are available on free loan to technical groups, universities, business and professional audiences, and other groups with specialized interests. All films are 16-mm-sound, varying from a ¼ hour to a ½ hour in length. Subjects include research and development, modern steelmaking, plastics, die-casting, infrared spectroscopy, compressed air power application, forging and grinding techniques and other subjects useful in fields such as architecture, civil engineering, construction, the metal trades, the chemical and petroleum industries. Copies of the catalog may be obtained by writing to *Modern Talking Picture Service, Inc., 3 E. 54th St., New York 22, N. Y.*

Keep Pace Electrically . . .

Just off the press is the illustrated planning guide which tells about the electrical industry's new concept, "Keep Pace Electrically." This theme was developed by the National Wiring Bureau, to help all branches of the industry benefit from increased sales through a unified appeal to prospects in the commercial market. The program guide shows how any organization or association can co-ordinate its advertising and promotion campaigns with that of the entire industry. Use of the "Keep Pace Electrically" emblem in contacts with customers and industry people will help to increase the overall impact of the entire industry effort, and will help each affiliation's products or services. A complimentary copy of "A New Sales Approach to the Commercial Market," is available from Commercial Promotion Department, *National Wiring Bureau, 155 E. 44th St. New York 17, N. Y.* Additional copies may be purchased at 25¢ each, plus forwarding charges. Please ask for PB-104.

Radiation Monitoring Booklet . . .

Automatic monitoring of gamma and beta radiation is discussed in a booklet recently released. Detectolab *DZ14* radiation supervisor may be used to monitor background in low-level counting rooms, in the working areas of "hot" laboratories, and in industrial radiography installations, among other numerous applications. The portable instrument will sound an audible alarm and flash a red warning light when radioactive background rises beyond preset level. *BJ Electronics, Borg-Warner Corp., 3300 Newport Blvd., Santa Ana, Calif.*

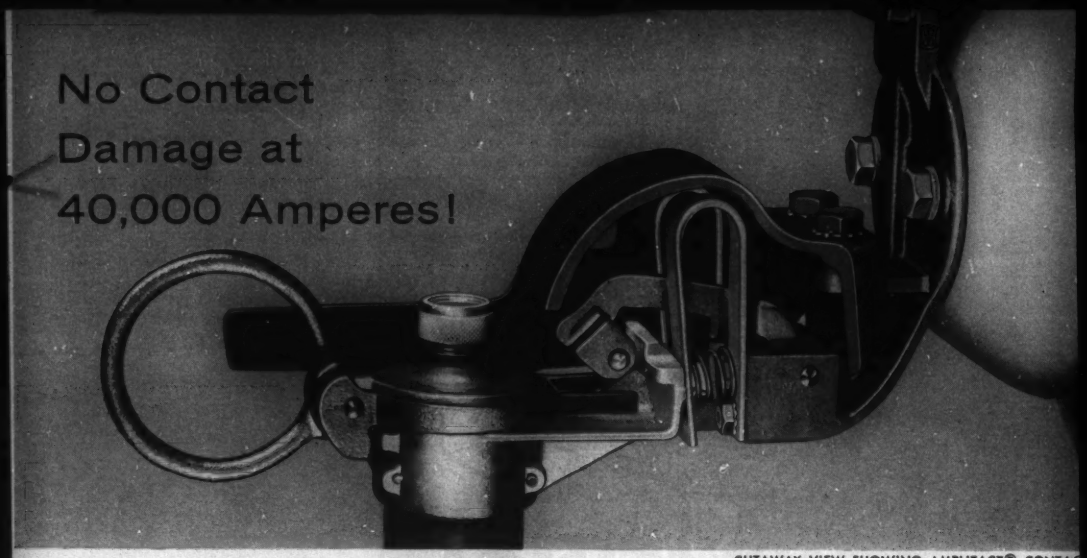
Student Booklet on Glass . . .

An illustrated booklet for students describes how glass is made and how it is widely used in science and industry. Written in nontechnical language, the booklet was prepared by Corning Glass Works as an educational aid for science students in high school and the first year of college. The booklet, "Glass in Science and Industry," covers the use of various types of glass in medical and space research, industrial and food chemistry, and in the electronics field. Laboratory Glassware Sales Dept., *Corning Glass Works, Corning, N. Y.*

Leak Detector Bulletin . . .

A 4-page brochure, (No. 1857), containing tables of conversion factors, formulas, performance charts, hints, and other useful information for users of mass spectrometer-type leak detectors, is offered by the Analytical and Control Division of *Consolidated Electrodynamics Corp., a subsidiary of Bell & Howell Co., 360 Sierra Madre Villa, Pasadena, Calif.*

(Continued on page 44A)



CUTAWAY VIEW SHOWING AMPLITACT® CONTAC

SOUTHERN STATES' POWER FUSES EMPLOY AMPLITACT® CONTACTS TO PREVENT CONTACT DAMAGE

Now, for the first time, "switch-proved" Amplitact® contacts are used on Southern States power fuses. Repeated tests at current ratings up to 40,000 amperes show no contact damage.

Used successfully for many years on Southern States air switches, Amplitact® contacts are now used on the new BPA and HPA Power Fuses.

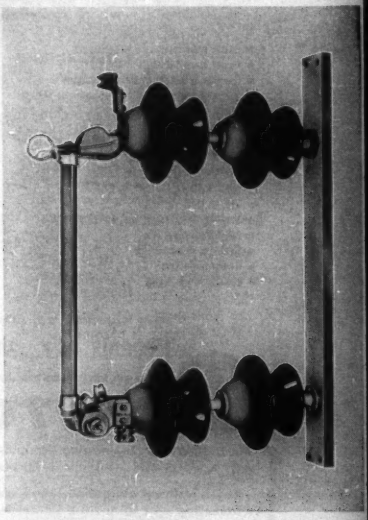
The Amplitact® harnesses electromagnetic forces generated on a high fault, increasing contact pressure when it is needed most.

While contact damage under extremely high fault currents has been more irksome than serious, the Amplitact® eliminates any possibility of damage.

These new power fuses have all of the outstanding advancements of the BP, MP, and HP power fuses introduced by Southern States in 1959—plus the reverse-loop contact. They have expendable cap fuse holders to provide dependable clearance of high or low current faults. Fuse holders are designed for easier handling and are equipped with a large operating eye. A stationary sleet shield gives better protection against icing and provides guidance when the fuse is slammed closed.

Low cost refusing in the field is accomplished with easy-to-use fuse kits.

Get your Southern States representative to give you full information about this important development in power fuses, or write direct for Bulletin 60 PF.



TYPE HPA POWER FUSE

KEEP PACE WITH ELECTRICITY

IN CANADA
Dominion Cutout Co., Ltd., Toronto

SS SOUTHERN STATES
EQUIPMENT CORP.
HAMPTON, GEORGIA

STIMULATING!

Motorola engineers are the most stimulated and enthusiastic individuals you'll find anywhere. And, for sound reasons.

First, the work. Electronics—challenging fields that plead for vision, creativeness and imagination.

Secondly, the company, An "engineers' company"—developed by technical minds dedicated to engineering excellence. A rewarding company—quick to recognize and advance skill. A secure, diversified company—not wholly dependent on one single market.

Thirdly, the place, Chicago—exciting and quiet. Cosmopolitan and suburban. Mid-America's nucleus of culture, education and entertainment—where everyone can find the perfect environment.

- Radar transmitters and receivers
- Radar circuit design
- Electronic countermeasure systems
- Military communications equipment design
- Pulse circuit design
- IF strip design
- Device using kylstrom, traveling wave tube and backward wave oscillator
- Display and storage devices

2-WAY RADIO COMMUNICATIONS

- VHF & UHF receiver
- Transmitter design and development
- Power supply
- Systems engineering
- Antenna design
- Selective signaling
- Transistor applications
- Crystal engineering
- Sales engineering
- Design of VHF & UHF FM communications in portable or subminiature development
- Microwave field engineers
- Transistor switching circuit design
- Logic circuit design
- T.V. circuit design engineering
- Home radio design
- New product design
- Auto radio design
- Mechanical engineering
- Semi-conductor device development
- Semi-conductor application work

Also splendid opportunities in

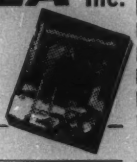
Phoenix Ariz., and Riverside, Calif.

EQUAL JOB Opportunity For All Qualified Applicants

MOTOROLA Inc.

Mr. L. B. Wrenn, Engineering Personnel Mgr., Dept. A
4501 Augusta Blvd., Chicago 51, Illinois

Without obligation, send copy of "Selecting an Engineering Career with a Future"



NAME_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

Trade Literature

(Continued from page 40A)

Bulletin on Merlon . . .

The bulletin compares the polycarbonate resin, Merlon (registered trade mark), with seven other plastics to show its unusual combination of characteristics which make it suitable for engineering applications now far beyond the range of present materials. The resin, a linear aromatic polyester

of carbonic acid, now is being evaluated for applications in the electrical, automotive, lighting, general industrial, graphic arts, and engineering fields. A few of these applications include switchboard connectors, coil forms, relay bases, printed circuit card holders, safety helmets, drafting film, and heat resistant diffusion lenses. Bulletin, No. TIB 41-M1, is available by writing *Mobay Products Co., 1815 Washington Rd., Pittsburgh 34, Pa.*

Engineering in Action . . .

Progress and achievements of 1959, related to engineering, are reviewed by Allis-Chalmers in the new edition of "Engineering in Action," recently released by the firm's Industries Divisions. Eleven chapters describe advances in equipment research and engineering for the generation, transmission, and distribution of power, as well as an extensive variety of equipment which utilizes that power. In addition, the latest research findings, including fuel cell advances and atomic energy projects in both fission and fusion fields, are reported. "Engineering in Action" annual is available as bulletin 25R9529. *Allis-Chalmers Manufacturing Co., Industries Group, Milwaukee 1, Wisc.*

(Continued on page 55A)

Trade Literature

(Continued from page 44A)

Poxylube . . .

A 4-page 2-color brochure explains the basic principles of Poxylube which is the new moly-base dry-film lubricant that is applicable to commercial production use; there is no expensive surface pretreatment necessary prior to application of the lubricant. *Poly Chem, Inc., 541 S. Webster Ave., Indianapolis 19, Ind.*

"Sub and Micro-Miniature Relays" . . .

A 24-page catalog covering a line of subminiature and microminiature hermetically sealed relays includes complete specifications on the "Powrmite" series of microminiature relays and its numerous subminiature types. The catalog includes information on mounting styles, available terminal types, and sockets, as well as dry circuit data. *Filtors, Inc., Port Washington, N.Y.*

Plumbing for Precast Concrete Decks . . .

A 12-page manual called "Plumbing for Flexicore Decks," explains in detail how openings can be designed into precast concrete decks and framed during construction, or hand-cut or drilled after the deck is in place. It also describes typical plumbing conditions and shows efficient methods of providing openings for each. *The Flexicore Co., Inc., 1932 E. Monument Ave., Dayton 1, Ohio.*

Short Form Catalog . . .

Key specifications and photos of instruments for nuclear research and process control are featured in the company's new short form catalog D-100. Copies may be obtained by writing to *Eldorado Electronics, 2821 Tenth St., Berkeley 10, Calif.*

Coaxial Connector Catalog . . .

An engineer's catalog of microminiature, snap-locking coaxial connectors gives complete details of the unique connectors, including electrical, mechanical, and environmental specifications and outline drawings. A wide variety of plugs, receptacles, caps, and adapters are shown in 50-, 75-, and 95-ohm impedances. Free copies are available from *EPL Technical Information Service, 2065 Huntington Dr., San Marino, Calif.*

Solid Lubricant Brochure . . .

A 4-page 4-color bulletin describes the wide industrial application of Molykote type *G*, a grease consistency lubricant that has proved to be a new production tool for industry. The bulletin discusses how Molykote *G* reduces galling, seizing, and metal pickup in high-pressure and high-temperature applications. Typical applications discussed in the bulletin include machine wear-in, fretting, threaded connections, highly loaded gears, cold metal forming, and press fitting. Instructions for applying the lubricant are also presented. A small sample tube accompanying Bulletin 126B may be obtained without cost from *The Alpha-Molykote Corp., 65 Harvard Ave., Stamford, Conn.*

Propulsion and Power Conversion Booklet . . .

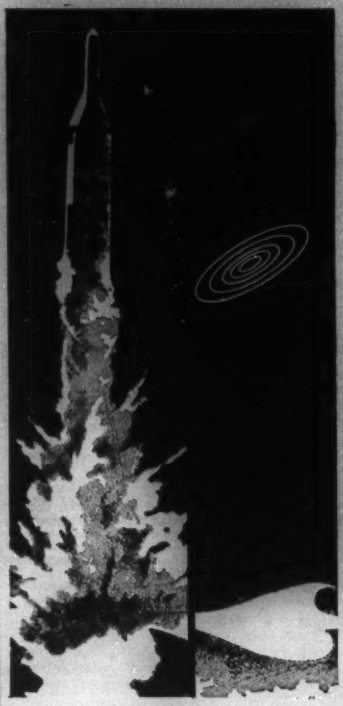
A 10-page booklet featuring a comprehensive description of three major approaches to advanced propulsion and power conversion systems for space vehicles describes the activities of Goodrich-High Voltage Astronautics, Inc. as presently embracing the fields of ion propulsion, colloid propulsion, electrostatic power generation, and other electrical conversion techniques. For a copy of this brochure, write on company letterhead to *Goodrich-High Voltage Astronautics, Inc., Burlington, Mass.*

Electronic Capabilities Brochure . . .

An 8-page 2-color brochure detailing expanded facilities and capabilities in the fields of electrical, electromechanical, electronic, and communications systems and components, is designed to give a condensed yet comprehensive picture of the Wheeler Electronic Corporation's research and development, engineering, and manufacturing departments, and their current work on projects in the fields of military aviation, weapons and ground support systems, missiles, and communications. *Wheeler Electronic Corp., 150 E. Aurora St., Waterbury 20, Conn.*

"Stunt Box" Control Device . . .

A 20-page 4-color brochure, entitled "Teletype 28 Stunt Box," provides users and potential users of Teletype model *28* equipment with an understanding of how model *28* page printers and automatic send–receive sets can be utilized to maximum capabilities. *Teletype Corp., Dept. SP-9, 4100 Fullerton Ave., Chicago 39, Ill.*



po-si'tion

A NOTE FOR TALENTED ENGINEERS:
We invite your inquiry as to important positions that exist at Nortronics' Precision Products Department (formerly the Military Products Division of American-Standard).

Plan your future with Nortronics' Norwood team and stimulate your professional growth. If you can qualify in one of several electro-mechanical areas you will work on challenging programs with professionally dedicated associates.

FOOTNOTE: *Excellent salaries for qualified engineers in both our Systems and Components Groups.*

Contact E. P. REARDON, *NORTRONICS Precision Products Department, Norwood, Massachusetts*

NORTRONICS
A Division of NORTHROP CORPORATION

Personnel Service, Inc.

(Continued from page 52A)

(not bulk conveyors), textile machinery. Knowledge of design and development of complex machinery and electro-mechanical devices. To do work from concept, design, through prototype fabrication and testing. For machinery manufacturer. $8400 up. San Francisco Peninsula. Sj-5105

DESIGNER: EE, age open, well experienced in design, draft and detail for consultant of general lighting and power, including substations. For general buildings (schools, commercial, industrial, hospitals, public); work done principally for architects in a consultant's office. Qualified to act as principal assistant to owner and eventually take over the office. $7200-9600. Sacramento Valley. Sj-5099

SALES ENGINEER: EE, ME, ChE, 29-35. Minimum five years sales or process plant experience; provide technical assistance to clients and promote sale of instrumentation (electric, pneumatic, or mechanical); to provide for control, actuators, direct reading or recording instrumentation for temperature, pressure, rate of flow, etc., in process plants (chemical, petroleum, petro-chemical, foods, etc.). For a manufacturer's district office. $6600 up and company car and fringe benefits. Los Angeles Headquarters. Sj-5099-R

DESIGNER: Electromechanical background, age open. Experienced in electric heating thermostats or closely related. Will develop additional new lines of thermostats and improve on present models. Should have knowledge of electric arrangement, base mountings, sheetmetal and molded products in shop production. Salary commensurate with experience. Oregon. Sj-5090-Ra

Men Available

New York Office

CHIEF ENGINEER, Electrical, B.S.E.E., 30 years' experience with consulting firms and electric utilities in design, construction and operation of utility, and industrial systems. Location desired: New York City or Newark, New Jersey area. E-175.

PLANT ENGINEER, E.E., 15 years' plant engineering, layouts, cost saving projects, drafting, maintenance, machine and tool design, building construction, safety in chemical and metal working plants. Location desired: East. E-176.

TECHNICAL EXECUTIVE CONSULTANT, E.E., Sc.D., an executive with constructive record of accomplishments in technical business and personnel management. Location desired: Continental U.S. E-177.

ENGINEER, B.S.E.E., two and a half years' experience in distribution line design and pole construction, one and a half years' in electrical drafting. Location desired: Prefer South, Southwest, West. E-178.

SENIOR ELECTRICAL ENGINEER, B.S.E.E., M.S. Physics. Twenty years' in high voltage laboratories in surge and sixty cycle techniques of which ten years' in charge of two laboratories. Responsible for all testing and measuring. Two years' teaching high voltage and power engineering overseas. Location desired: West, U.S. or Foreign. E-179.

ELECTRICAL ENGINEER, Industrial Power, 25 years' industrial electrical construction, supervision, engineering and administrative; engineering design, shop drawings, and installation. Wide range of industrial power work, process controls, general lighting, wire communications, and signal systems. Will accept limited travel; will relocate. E-180.

ELECTRICAL ENGINEER, B.S.E.E. Experience in distribution, metering, relaying systems, control systems for large steam generating units. Design of ships electrical installation. Maintenance of electrical installations. Speak Portuguese and Spanish. Seek foreign assignment. E-181.

Chicago Office

DIRECTOR OF ENGINEERING OR CHIEF ENGINEER, B.S., S.B., S.M., E.E., 28 years' in electromechanical equipment; seven years' college teaching E.E.; seven years' designing voltage regulators and associated controls; six years' designing industrial induction motors and motor controls; three years' designing automotive and ordnance generators; five years' engineering management including three at staff level; one and a half years' plant management including administration of engineering. Location desired: Anywhere east of Rockies. E-1064-Chicago.

ELECTRICAL ENGINEER, B.S.E.E., nine years' experience designing all types of crane controls, AC and DC, experience in magnetic amplifiers and saturable reactors, hold patent on crane hoist control. Location desired: Midwest. E-1080-Chicago.

ELECTRICAL ENGINEER, B.S. in E.E., five years' with consulting engineering firms engaged in power plant and refinery design. Four years' with electric utility doing electrical design for existing power plant alterations. Location desired: Midwest or Southwest. E-1081-Chicago.

ELECTRIC POWER ENGINEER, B.S.E.E., eleven years' of experience in the design and operation of rural and urban power distribution and transmission. Technical as well as supervisory experience. Hold professional license. Location desired: Midwest and West. E-1084-Chicago.

GENERAL MANAGER OR SALES: Organized assembly and sales electronic components 11 states, two years' sales engineering induction heating. Four years' process engineer aircraft engines. Thirteen years' field engineering industrial electronics. OEM following. Location desired: Midwest preferred, but will relocate. E-1085-Chicago.

San Francisco Office

PROJECT ENGINEER: EE, 37. Rounded experience in project management, project engineering and design group supervision. Registered Prof Engr, with training in electronics. Seventeen years experience with nuclear reactor manufacturer, electric utility, shipbuilder, electronic equipment design and builders. Experienced management, system design, instrumentation and control, construction. Salary open. Prefer West Coast. Home: East. Se-1418

JUNIOR ELECTRONIC ENGINEER, graduate, 35. Thesis, transistorized photo electric amplifier. US Air Force radar operator and amateur radio operator. Hobbies: Building radio controlled aircraft, boats and high fidelity equipment. Wants starting position in any electronics product or business. $5400-$6000. Prefer San Francisco Bay Area. Home: San Francisco. Se-1692

COORDINATOR—ADMINISTRATOR: EE, 45. Eight years experience supervision, direct construction, plans, schedules, contract preparation and administration for hydroelectric projects, substations, transmission lines, miscellaneous plants for utility and consultant. Six years chief planning and developing for Bureau of Reclamation. Four years operation, maintenance, design, drafting dredge motor and pump, for CEC. $11,000. Prefer: West, Mountain States, Hawaii. Home: Oregon. Se-1501

ELECTRICAL OR ELECTRONIC DRAFTING: Phys, EE, 67. Many years experience electric design, draft, electronic drafting for utilities, shippards, power transmission equipment, steel plants for consultants, utility, government and manufacturers. $6600. Prefer San Francisco Bay Area. Home: San Francisco. Se-1485

SUPERINTENDENT OR PLANT ENGINEER: EE, 35. One year superintendent in charge of construction of homes, land development, including estimates, contracts, customer contact. Two years investigation of problems of production, transmission and use of electric power for aluminum production. Two years lecturer, electrical engineering. One year sales of low and high voltage switchgear for manufacturer. $6000. Prefer: San Francisco Bay Area. Home: San Francisco East Bay. Se-1446

FIELD SERVICE ENGINEER: EE, 38. Installation and service of marine radar and Loran equipment. Experienced in power and generating systems. $6600. Prefer California. Home, California. Se-1376

DESIGN OR CONSTRUCTION ENGINEER: EE, 46. Twenty years experience design, construction, installations, maintenance on power distribution, paper mills, copper refining plants, steel plants, oil fields and refineries. $9600. Prefer San Francisco, or Foreign. Home: San Francisco. Se-1275

DESIGNER: EE, 49. Experienced in electrical design of industrial plant power systems, substations, distribution, control and lighting. Also construction engineer on industrial plants and generating station. $9600. Prefer: Northern California. Home, California. Se-1272

SENIOR DESIGN, DEVELOPMENT ENGINEER: MSEE, 47. Electronic circuitry, transistors and tube circuits, pulse technique, communications, TV. Salary open. Prefer: San Francisco Peninsula. Home: San Francisco Peninsula. Se-1206

ADMINISTRATION OR SALES ENGINEER: Electronic graduate, 40. Two years administration of engineering department for mining equipment manufacturer. Two years sales, design, install accounting and control systems. Four years direct planning, scheduling of production of magnetic tape recorders. Two years instructor of electronics. $10,000. Prefer: West or East Coast. Home: California. Se-1192

ELECTRICAL DESIGNER: EE, 34. Sound academic training, more than eight years experience in electrical design in consulting and contracting. Strong in distribution, lighting and motor control. Mechanical experience. $9000. Prefer: Southern California. Home: Ohio. Se-1106

DESIGNER OR CONSTRUCTION ENGINEER: EE, 33. Two years design, construction, maintenance, operation, oil field production, power plant, distribution; for oil company. One year design, test transistor circuit audio amplifiers for instrument lab. One year development, sales motor controls. Two years supervise construction of airfields, power plants, distribution, water and fire systems for consultant. $10,000. Any location. Home: Massachusetts. Se-1088

GENERAL MANAGER OR SALES: EE, BusA, 48. Extensive background in general management, sales and sales management of industrial products both mechanical and electrical. Know financing, cost analysis, production control and sales for industrial company. Can handle people and get results. Want progressive company. $15-20,000. Prefer: San Francisco Bay Area. Home: San Francisco Bay Area. Se-391

SALES ENGINEER, 50, Prof EE Lic, California. Eight years manager on sales of transformers, circuit breakers, electronic equipment. Twenty-three years experience as apparatus engineer, system planning, instructor on radar and communications, electric equipment for manufacturers, utility and Navy. $12,000. Prefer: Southern California. Home Southern California. Se-182

DESIGNER, MAINTENANCE: EE, 31. Four years design, layout lighting, telephone, communications, distribution, field engineering and inspection, maintenance for consultants and calculator manufacturer. Two years installation, maintenance of elevators. $8100. Se-1800

PLANT ENGINEER: EE, 37. Eleven years varied industrial experience in design, construction, maintenance and planning for plant facilities. Good record with people, problems, unions and operations. $10,800. Prefer: San Francisco Bay Area. Home: Washington. Se-1684

ESTIMATOR, SPECIFICATION WRITER: CE, EE, 51. Twenty years experience estimates, specifications, design, plan on civil, structural, mechanical and electric projects, including dams, roads, heating and ventilating, plumbing, housing for industrials and government. $8400. Any location. Home: Northern California. Se-505

(Continued on page 58A)